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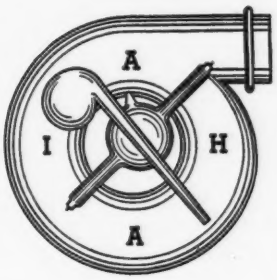

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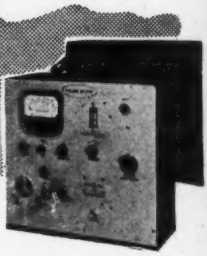

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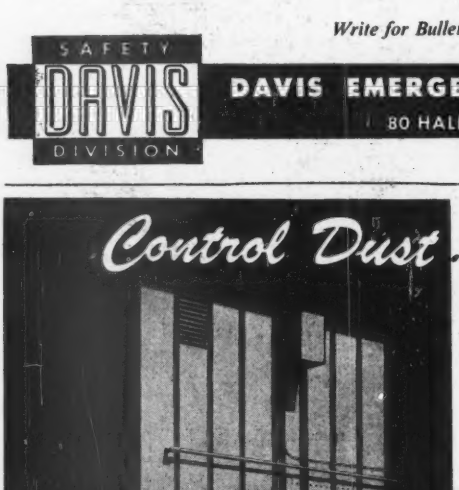

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Volume 12 DECEMBER, 1951 Number 4

Meteorlogical Factors in Atmospheric Pollution Problems

MAYNARD E. SMITH
Brookhaven National Laboratory

A RELIABLE means of estimating the dispersion of stack effluent has long been sought, especially since 1945. Although formulae for calculating the dispersion from stacks are available, it has been difficult to discover sufficient empirical data to evaluate their validity. Dispersion data as such are relatively plentiful, but in many cases the presence of nearby sources of similar nature and the difficulty of obtaining accurate measurements of low concentrations have rendered the data of questionable value. Complete information on the micrometeorological factors associated with dispersion from a particular source is so rare as to be almost unique. The standard weather observations do not provide such data, and a complete installation represents a considerable investment.

In 1947, with these facts in mind, the staff of Brookhaven National Laboratory set out to determine the relationship between the dispersion of cooling air from the nuclear reactor and the associated micrometeorological conditions. The basic installation included two triangular steel towers, the larger of which (420 ft.) was equipped with meteorological equipment and a 20-in. stack for the purpose of emitting an oil-fog test effluent. More complete descriptions of the installation and the program may be found in other publications.[1,8,9] Between 1948 and 1950, over 40 oil-fog runs of one to three hours' duration have been made, covering a wide range of meteorological conditions. Ground-level concentrations of the effluent have been measured with photometric densitometers during each of the runs.

The Brookhaven area has many advantages for this type of work. Competing smoke sources are generally insignificant, the terrain is quite flat and the vegetation reasonably uniform; sufficient roads are available to allow a good distribution of sampling points. Despite these advantages, the data cannot be considered completely reliable. Careful investigation has not yet eliminated all significant error from the photometric sampling devices, and there is still some question as to the homogeneity and stability of the oil-fog particles. For these reasons, it is not advisable to use the data for exact quantitative comparisons with theoretical calculations, although certain generalizations can be made.

Within the past several months, it has been possible to make preliminary comparisons between the oil-fog data and radiation emanating from the radioargon present in the cooling air from the nuclear reactor.[9,12] These data are not sufficiently complete to be presented in detail, but the initial results show no tendency to discredit the oil-fog data.

The work of O. G. Sutton[10,11] was selected in 1948 as the most acceptable theoretical treatment of the dispersion of effluent from elevated sources, and initial esti-

Research carried out at Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.

Presented at the 1951 Industrial Health Conference, Atlantic City, April 26, 1951.

mates of ground level concentrations were made on the basis of these formulae and the then scanty climatological data available for Brookhaven. The present paper includes comparisons of oil-fog data with Sutton's theoretical values of the maximum ground concentrations (χ_{max}) and the distances of these from the source (X_{max}). Detailed summaries of the measured oil-fog concentrations at ground level are available elsewhere.[6]

Lapse Conditions

ON ALMOST all sunny days, heating of the ground surface results in a rapid decrease of temperature with height in the lower layers, usually at a rate associated with instability (-1.0 to $-2.0°C/100m$). Large thermal eddies are present, causing portions of the smoke trail to be carried alternately to the ground and to levels above the tower at intervals of the order of five to 15 minutes (Fig. 1). Wide horizontal oscillations are also present. With light winds (2-6 mph.) these eddies predominate. Stronger winds cause an increase in high-frequency frictional turbulence which is superimposed on the longer period fluctuations. The dispersion is such that smoke is seldom present continuously at any point on the ground, at least within the first 50 stack-heights. Instead puffs of effluent are carried over the sampling point at distinct intervals; the concentrations varying from high values to zero.

A comparison of hourly mean oil-fog concentrations with Sutton's theoretical values has shown the latter to be high by about a factor of 10. The distance of the maximum concentration from the source appears to range from five to 20 stack-heights; somewhat less than the predicted 22 stack-heights. These maximum concentrations close to the stack have all been associated with very light winds.

Neutral Conditions

DURING cloudy weather and moderate to strong winds, the temperature generally decreases with height in the first 400 ft. above ground at a rate of 0.0 to -0.7°C/100 meters. The turbulence is almost entirely frictional, with high-frequency eddies predominating. These are the conditions comparable to the "average" described by Sutton.[10, 11] The oil-fog is dispersed in a gradually widening cone that first reaches the ground at a distance of 10-30 stack-heights. The effluent in this case is often continuously present at sampling points, with much smaller variations in concentration than are found in lapse conditions.

The hourly mean oil-fog concentrations in neutral cases have been found to be less than the predicted values by a factor of approximately four. The distance of the maximum concentration from the source is found between 20 and 50 stack-heights, comparing favorably with the predicted value of 41.

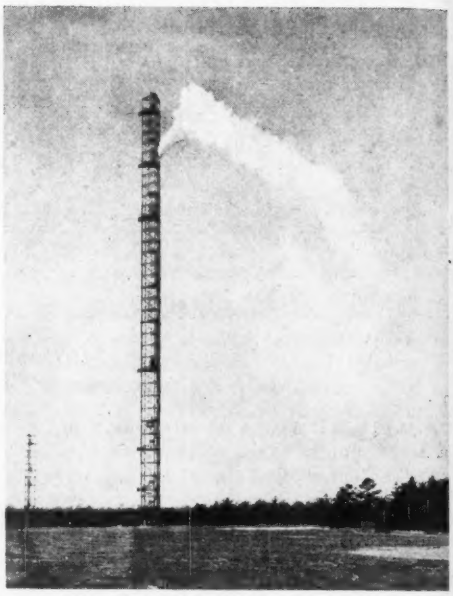

Fig. 1.
Dispersion in Unstable Air. The oil-fog trail shows the effect of large convective eddies; in this case a portion of the plume reached ground-level 250 feet from the tower base. The wind speed was 3 mph, and the vertical temperature difference (T_{410}—T_{37}) was —1.0°C.

Inversion Conditions

THE character of dispersion alters markedly when the temperature increases

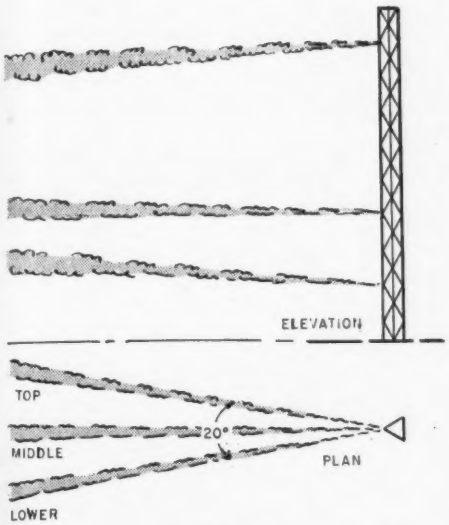

Fig. 2.
Dispersion in Stable Air. Three separate oil-fog trails (355 ft., 150 ft. and 50 ft.) illustrate the lack of vertical dispersion during temperature inversions. The APPARENT rise of the lowest trail and descent of the highest trail result from the marked vertical shear in wind direction. The wind speed at 355 ft. was 16 mph, and the temperature difference (T_{410}—T_{37}) was +2.5°C.

with height. The effluent trail spreads out in a thin sheet that widens horizontally but not vertically downwind of the source (Fig. 2). Under these conditions, no oil-fog has ever been detected at ground-level, even at distances of 350 stack-heights. This is the only meteorological situation under which no agreement exists between the theoretical values and observation, for the former predicts large ground-level concentrations at distances of 70-100 stack-heights.

Sampling Periods

THE data presented in the preceding paragraphs would seem to indicate that the formulae published by Sutton in 1947 overestimate the actual effluent concentrations at ground-level. Other published results indicate the same tendency.[2] However, it is necessary to reconsider certain factors before adopting this view. Sutton's calculations were based on meagre data, as was pointed out by the author himself. The work was based on data obtained from ground-level sources over very flat terrain during neutral meteorological conditions. The standard sampling period was *three minutes*. The Brookhaven data presented herein are *hourly* mean concentrations over more rugged terrain.

Under both lapse and neutral conditions, the eddies sampled in a three-minute period do not include certain of the longer period fluctuations that are reflected in an hourly mean. This is more particularly true of the lapse condition. It is thus quite reasonable to anticipate that the long-period samples would indicate lower mean concentrations. Essentially it is a matter of determining the dividing line between the largest eddies encompassed in the term "turbulent diffusion" and those regarded as "shifts in the mean wind." In the absence of an accepted definition, the decision rests largely in the type of problem faced by the individual investigator.

It is possible to consider the dispersion of *individual* puffs of oil-fog under lapse conditions as resulting from turbulent diffusion, and the distribution of these puffs over a long period as resulting from shifts in the mean wind. If this approach is adopted, one would expect the mean concentrations in individual parcels of effluent carried to the ground under lapse and neutral conditions to show agreement with the Sutton predictions. The data obtained at Brookhaven indicate such an agreement. One would also expect that an increase in the period of sampling would show less change in the mean concentration values under neutral than under lapse conditions, for the large, thermal eddies are not present under neutral conditions. The Brookhaven oil-fog data do indicate closer agreement between theory and observation in neutral cases than in lapse.

The inversion case cannot be reconciled on this basis. The difficulty here lies without question in the lack of data available at the time of publication of the Sutton paper. Isotropic turbulence, as assumed by Sutton, definitely does not maintain when the air is stable; the vertical eddies are almost completely suppressed, whereas the

horizontal fluctuations continue at a much reduced intensity. Thus, for elevated sources, ground-level concentrations are not present during inversions.

Estimation of Ground-Level Concentrations

IN VIEW of the preceding comments, the question naturally arises as to the most acceptable methods of arriving at estimates of ground-level concentrations from elevated sources under the various meteorological conditions. This would depend primarily on the degree of accuracy desired by the investigator, and of course on the location and nature of the source. With regard to the latter, it would be well to note that the Brookhaven data were obtained for an effluent whose particles are so small (.3μ mean radius) that the fall velocity is insignificant. Johnstone and Baron[4] have suggested a method of correcting for variations in effluent particle size. Also the Brookhaven terrain is uncomplicated, and it is *not* anticipated that these results or any current theoretical treatment could be applied directly to rugged terrain.

Assuming that the investigator desires only an order of magnitude estimate of the maximum concentrations that might be observed from a particular source, the Sutton formulae are probably adequate for lapse and neutral conditions. The Brookhaven tests have provided no detailed information on ground-level concentrations that might be found with a *low* (10-25 meter) stack under inversions.

An empirical method of estimating ground-level concentrations from meteorological data obtained at Brookhaven has been developed. The essential concept involved is that discussed earlier; that the Sutton formulae describe the diffusion over short periods, but that special treatment is required when the periods of one or more hours are considered, owing to variations in mean wind direction. The process is to determine from observations extending to the height of the stack involved, the distributions of wind direction corresponding to various meteorological conditions, and to apply the Sutton formulae according to the percent of time during which the wind blew from each direction. Thus, if a given direction were represented for 20% of the period, one would expect a mean concentration of 20% of the theoretical value.

This method, described in detail by Lowry[7] is arduous and requires complete meteorological information for proper application. It is necessary to establish the gustiness classifications[3,9] associated with various stability conditions and wind speeds, and to determine the frequency distributions of wind direction within these classifications. The results have been found suitable for the rather detailed needs of the Laboratory.

A simplification of the method has been developed by Lowry.[5] The method requires only wind speed and direction at the height of the source, and provides a means of obtaining engineering estimates of maximum ground-level concentrations and the distances of maximum concentrations with minimum effort.

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Air Pollution and Methods of Control

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AIR POLLUTION is the general term applied to atmospheric nuisances which are produced by contaminating substances. These substances may occur in the form of smoke, dust, gases, vapors, fumes, and mists. Smoke and dust consist of varying mixtures of oily materials, carbon, silicious materials, compounds of a number of metals, pollen, and microorganisms. The most important gaseous contaminants are carbon dioxide, carbon monoxide, sulfur dioxide, oxides of nitrogen, organic acids, aldehydes, hydrogen sulfide, and hydrocarbons. The chief sources of contaminating substances in urban and industrial areas are household, public and industrial incinerators, refineries, chemical plants, metals industries, mineral and earth processing industries, internal combustion engines, power plants, and homes heated by coal or wood. In agricultural regions the primary sources of pollution are dust storms and the operation of orchard heating equipment.

Causes of Air Pollution

THE emission of contaminating substances is the immediate cause of air pollution. The extent of the resulting pollution is, however, greatly conditioned by topographical and meteorological factors. Mountains and valley walls may restrict wind movements and thus increase pollution. Natural wind channels may conduct pollutants away from the producing source and into other areas. Large scale meteorological situations exert a profound influence upon air pollution. Weather types, prevailing winds, high pressure areas, and stagnancy all are important. High pressure areas, which always bear major responsibility for extreme cases of local pollution, are also the most important single cause of California's air pollution problems.

A high pressure area is ordinarily associated with an atmospheric condition known as *inversion*, in which air temperatures near the ground are lower than those higher up. The warm air above then acts as a lid holding down the contaminating substances and preventing their escape upward. Since high pressure areas are also usually associated with an absence of strong winds, pollutants have little chance of being carried away by horizontal air movements. Diurnal inversions, which have no special relationship to high pressure areas, also occur, but their duration is normally short; consequently their influence on air pollution is not great.

The meteorology of the continental United States indicates that conditions for high pressure areas and wind stagnation are much more pronounced in the southwest than in the eastern and northern sections of the country. The existence of high pressure areas is a dominant characteristic of the California coastline from May through October. Thus California reveals a climatic predisposition towards air pollution. Only the lower rates at which contaminating substances are emitted in most areas has, as yet, prevented severe and widespread air pollution in California. It has been said that if the local situation in Los Angeles (pollution sources and local topography) were similar to that in the Monongahela Valley at Donora, Pennsylvania, the Los Angeles area would be unlivable half the year.[1]

Some degree of air pollution is prevalent in all the larger California cities, and in many of the smaller ones.[2] The problem in Los Angeles is well known, having developed, for the most part, during the past few years, and is now being carefully studied.

Nineteen smog days were reported in Los Angeles during the period from December 1, 1949, to November 30, 1950. The months of most frequent occurrence are August, September, October, and November, when the combination of weak air currents and high-pressure inversion is most pronounced. Scientific studies report

Los Angeles smog to be largely a man-made phenomenon, consisting of a complex mixture of gases, solid particles, and liquid droplets.[3] The contaminants are produced from the burning of fuels and rubbish by the public and by industry, resulting in a daily emission, within the county, of 2,000 tons of chemicals. Approximately 40% of these pollutants come from industrial sources, and 60% from the general public (automobiles, trucks, buses, burning of garden trash, and heating of buildings). Although centering in the vicinity of the City of Los Angeles, the smog sometimes drifts over the surrounding region, with resulting nuisance and crop damage covering a wide area.

In the San Francisco area air pollution is not now a serious problem, although it appears to be increasing. The area's ring of low mountain ranges restricts horizontal air flow, thus increasing the effect of high pressure areas, and creating a susceptibility to atmospheric contamination. Only the dominant west-to-east wind pattern ordinarily prevents contaminants from reaching high concentrations. "That a smog problem could develop which would call for extensive and expensive corrective measures on the part of everyone in the area is evident from the way certain sections of the Bay Area are adversely affected by such a simple operation as an open trash dump."[4]

Major existing nuisances recognized in the San Francisco Bay area include burning garbage dumps, automobile exhausts, and black smoke.[5] Instances of widespread contamination by odorous substances have also occurred and are believed to have been produced by a combination of industrial fumes, tidal-flat smells, and the open burning of garbage dumps. Four attacks of this nature were observed between September 20 and November 3, 1950.

The topography of the San Francisco Bay area is such that the outlying valleys of Napa, Santa Clara, Livermore, and the others, have much to lose if air pollution develops, because they will, under proper wind conditions, act as catch basins for pollution from other parts of the area. Even the more distant cities of Sacramento and Stockton are directly in the path of air pollution moving eastward from the San Francisco area.

The major problem in Stockton is, however, caused by peat dust storms in the surrounding farmland, which usually blow during limited periods of spring and summer dryness. Dust storms also occur in the Bakersfield area and on the west side of the San Joaquin Valley, 20 of them having been observed in 1948. The Christmas storm of 1948 left an estimated damage of a million dollars. Causes of these dust storms are lack of moisture, high winds, cultivation of submarginal lands, and failure to utilize farming methods which would help prevent wind erosion.

Pollution produced by the smudges burned to protect orchards has long been a serious problem in many parts of California, particularly in the citrus areas.

When California's air pollution problems are compared with those of the industrial east, certain basic differences appear. Little coal is burned in California cities, gas and oil being depended upon by both domestic and industrial users. In the east, on the other hand, coal smoke has been the most important single pollutant. In California cities the greatest accumulation of air pollutants occurs during the summer and early fall months, when visible smoke emission is at a minimum. The heaviest pollution of eastern cities occurs during the winter months when coal smoke is most in evidence.

These differences are reflected in the air pollution control activities of eastern and northern cities, which have concentrated almost exclusively on the reduction of smoke. Having cleared away the smoke sufficiently to become aware of other nuisances, some cities are now broadening their control programs to cover gases, fumes, mists, and other less visible pollutants. These latter constitute a much more difficult and complex control problem. Thus California's air pollution experience skipped the coal-smoke stage and plunged her directly into the problem of over-all pollution. This is one of the chief reasons why Los Angeles' research and practice, directed toward the over-all problem, is recognized as outstanding throughout the United States.

Effects of Air Pollution

HEALTH EFFECTS: Evidence regarding the health effects of air pollution is suggestive, but inconclusive. During critical episodes of extreme pollution, such as the Donora, Pennsylvania, case, or that occurring in Belgium's Meuse Valley in 1931, the effects of pollution on health became obvious. The influence of more "normal" levels of pollution is, however, extremely difficult to evaluate. The British have collected a mass of data which point toward a probable health effect of smoke, and on the strength of this have judged domestic and industrial smoke to be among the four primary reasons for the excess of urban mortality over rural. A recent Maryland survey presented evidence showing the frequency of the common cold to be higher in areas of heavy dust fall than in regions with little pollution.[6] Other American and British studies indicate a possible connection between air pollution and the incidence of respiratory and pulmonary diseases.

Health officers have pointed out that most of the industrial air contaminants are the same as those causing disease among workers.[7] Consequently these same diseases will be produced among the general population of a polluted area, if the effective concentrations rise sufficiently high. Although the maximum acceptable concentrations of various contaminants are well established for industrial workers, these standards are based on eight-hour exposure periods. Little has been done to develop similar standards based on longer exposure periods up to 24 hours per day. It has been suggested that maximum acceptable concentrations for 24-hour exposure periods should be as low as one-tenth of the concentrations acceptable for an eight-hour exposure, thus compensating for loss of the recuperation achieved during the 16 hours an industrial employee is away from work.[8] Another important factor which must be considered in attempting to estimate the influence of air pollution on health is the probable greater harm done the aged and infirm. Certainly these people bore the brunt of the Donora disaster.

Serious health effects of dust pollution have been recognized by medical researchers studying army camp occupants in the San Joaquin Valley.[9] Higher rates of incidence of coccidioidomycosis (valley fever) were found to be closely associated with periods of heavy dust contamination. Dust control measures undertaken in the camp areas brought definite improvements.

The psychological depression and emotional enervation produced by a smog-shrouded environment should undoubtedly be classified among the health effects of air pollution, but they are even more difficult to evaluate. Although neither measurable nor readily definable, these influences are obvious to anyone who has lived in an area experiencing air pollution.

NUISANCE EFFECTS: Irritation of the eyes and other mucous membranes is a well known and increasingly evident result of air pollution in some areas. Approximately one fourth of the country's ninety-nine largest cities have reported occasional eye irritation, and a few indicate that it has been observed frequently. Los Angeles is thus not unique in this respect, although its attacks are more severe. Mucous membrane irritants include respiratory irritants such as sulfur dioxide, chlorine, aldehydes, and hydrogen sulfide. Mixtures of these and other compounds, both organic and inorganic, probably undergo chemical reactions in the air to produce additional powerful irritants. It is thought that such reactions may produce the eye-irritating qualities of Los Angeles' smog, although the responsible factors have not yet been specifically determined.

Malodorous substances in the air constitute another type of pollution with definite nuisance effects. Oil refineries, asphalt plants, soap and glue factories, sewage disposal plants, internal combustion engines, and other sources may produce bad smelling contaminants. One authority indicates that the chemical compounds most frequently associated with unpleasant odors are "sulfides, disulfides, mercaptans, thiocyanates, isocyanides .... recognizable as malodorous at less than 0.1 ppm (parts per million), and some as low as 0.0000001 ppm."[10]

A further nuisance effect of air pollution is its impairment of visibility. When this impairment becomes extreme, how-

ever, it is not just a nuisance but also a real danger to moving vehicles, ships, and airplanes. In the eastern and northern industrial cities smoke is recognized as one of the major causes of visibility reduction. Research in the Los Angeles area has succeeded in fixing the blame there on three types of contaminants. Hygroscopic (water absorbing) substances which form mists of water droplets account for from 30 to 80% of the reduction; carbon, tar, and metal particles, 10 to 50%; and crystalline metallic compounds, 10 to 50%.[11]

ECONOMIC EFFECTS: Estimates of economic effects of air pollution in the U.S. vary widely, but all agree that losses are considerable, whether given in lump sum or in per capita figures. "Some years ago, the Commerce Department estimated that the cost of damage from smoke in various cities of the United States amounts to from $8 to $20 per inhabitant annually. The chief smoke inspector of one large American city has announced his estimate that smoke damage in and around American cities amounts to approximately $17 per inhabitant per year. The United States Geological Survey has indicated that smoke damage to merchandise and buildings alone in this country reaches a figure of at least $500,000,000 per year .... The chairman of the National Conference on Sanitation of New York City indicates that the material loss to fabrics, household equipment, and buildings amounts to at least $16 per capita per year, or a loss of about $100,000,000, in greater New York City alone .... At least three independent estimates place the economic loss from air pollution in the city of Chicago at approximately $20 per person per year."[12]

CROP AND LIVESTOCK DAMAGE: It is well known that heavy concentrations of certain pollutants can do serious damage to crops and livestock. In a number of cases obvious effects of contamination by smelters have been observed in which heavy doses of sulfur dioxide have injured vegetation, and sometimes arsenic has poisoned livestock. Again it is more difficult to assess damage caused by the lower, but still appreciable, concentrations generally associated with industrial air pollution.

Sulfur dioxide concentrations above approximately 0.5 ppm are definitely injurious to plants, but concentrations up to 0.2 and 0.3 ppm present during the growing season are probably not detrimental if the exposures are not of long enough duration to cause leaf injury. In the Los Angeles area much crop damage from sulfur dioxide has been observed, although this kind of injury has now been reduced through efforts of the air pollution control district and of the industries involved. Fluorides may cause plant damage but only if present in relatively high concentrations. However, animals grazing fluoride-contaminated vegetation have been affected, even when the plants themselves have not been injured.

It has recently been shown that the major crop-damaging contaminants in the Los Angeles area are unsaturated hydrocarbons, the primary source of which is petroleum. These compounds escape into the air where they react with ozone or with oxides of nitrogen. The oxidation products cause plant injury by scorching and dehydrating the leaves, turning them black. Crops whose foliage is the salable portion, such as lettuce, spinach, and alfalfa, are most susceptible to damage by these hydrocarbons. In the Los Angeles area effects of this kind have been traced as far as Oceanside, 70 miles southeast of central Los Angeles, Oxnard, 50 miles northwest, Castaic, 43 miles north, and Yucaipa, 50 miles east.[13] Recent losses from single attacks have been estimated at $125,000.

Methods of Control

ELIMINATION AT THE SOURCE: A great volume of chemical and technical research has been done on problems of eliminating or controlling air pollution nuisances. The earliest nuisance so attacked, and the one for which adequate controls are now well established, was the problem of domestic and industrial smoke. The Mellon Institute long ago learned and attempted to publicize the simple principles on which smoke prevention is based. There are two alternatives: (1) either burn smokeless fuels (hard coal, gas, and oil), or (2) burn other fuels smokelessly (bituminous coal). To the extent that smokeless fuels

are economic and available, they can be used; to the extent that other fuels must be used, they can be burned smokelessly with good equipment if it is properly designed and correctly operated. The smoke-reduction programs of the eastern and northern industrial cities have consisted almost wholly of governmental and voluntary efforts to insure the general application of these principles. Where the efforts have succeeded, smoke nuisances have been strikingly reduced.

Much more difficult problems are presented by dusts, gases, vapors, and fumes. Nevertheless, considerable progress has been made toward their solution. Scrubbing and absorption towers can be used to remove many vapors and gases, especially acid vapors. Much progress is being made in the use of mechanical and electrostatic precipitators for dust and fly ash collection. The bag filter (vacuum cleaner principle), constructed of glass, asbestos, or other fibers, shows particular promise for cleaning high temperature gases. Venturi scrubbers have been used effectively in the case of sulfate produced by paper pulp manufacturers. Ultra-sonic precipitators show promise for high temperature work and for extremely small particles but as yet are primarily in the developmental stage. Water sprays are good for collecting large dust particles but have been overrated by many plants which have attempted to use them as a solution to all abatement problems. Special mechanisms such as fog chambers are still in the developmental stage.

Other efforts at control which have been successful in special cases, but which cannot be applied generally, include the use of raw materials free from objectionable impurities and the redesign of processes to eliminate undesirable emissions. An example of the latter is the conversion from chamber type to contact sulfuric acid plants. Sometimes the pollutants have economic value in themselves, providing an added incentive to collect and sell them as by-products. Sulfur, for example, has been produced as a by-product of petroleum refining, and other industries have recovered and sold fly ash, lead oxide, bromine, and chlorine.[14]

DISPERSAL OF CONTAMINANTS: Not only can the nuisances of pollution be reduced through elimination at the source, but also they can be reduced by the use of techniques for more effective dispersion of polluting substances. The tall smoke stack is the device most frequently relied on. Although able to insure a lower degree of contamination in the immediate plant area, smokestacks have a more limited influence in reducing widespread pollution, particularly when it is associated with the deep temperature inversions accompanying high pressure conditions. Observations made at the Hanford, Washington, atomic works indicate, however, that smoke stacks built 300 to 400 feet high are tall enough to pierce the lower and shallower radiation-type inversion layers and so help prevent the accumulation of smog.[15]

The concept of "meteorological control" has been discussed as a method of securing maximum dispersal and has been utilized in several instances.[16] Under a system of meteorological control, pollutants are emitted at varying rates, depending upon existing or prospective atmospheric conditions affecting dispersal. The pioneer example of meteorological control is that established by the Consolidated Mining and Smelting Company at Trail, British Columbia, under supervision of the International Trail Smelter Arbitrary Tribunal. The system was adopted to prevent damage from sulfur dioxide and utilizes a seasonal and diurnal control, depending upon *contemporary* meteorological observations.

Since the atmospheric conditions causing smog are known to build up slowly, they can be predicted over longer periods than most other meteorological phenomena.[17] Hence, it would, in most cases, be relatively simple to utilize forecasting, as well as contemporary observations, in a system of meteorological control. Specified plant operations could be reduced before the smog-producing condition reached its peak, and intense smogs prevented. An example of the successful use of forecasting is the practice at the Brookhaven National Laboratory (AEC), Long Island. Probably the chief limitation on meteorological control is in those industries whose operations require long start-up or shut-down times.[18]

PLANNING AND ZONING CONTROLS: Another kind of control for air pollution nuisances is generally available to cities and counties through the zoning of land areas for special uses. Industries which are obnoxious because of their emissions may be restricted to zoned areas distant from residential sections.[19] This type of control can prevent or reduce local nuisances but is of less avail against widespread pollution problems. When used successfully as a method of air pollution control, zoning requires long-term foresight and careful work on the part of local planning agencies. A similar approach has been employed in a few instances by zoning appeals boards which have prescribed pollution abatement as a condition for the continuation of an existing use. The planning or zoning board may also allow a new industry to establish itself in a specified location, on the condition that satisfactory pollution abatement equipment will be installed.

Methods of Solving Special Problems

ODORS AND SMELLS: Specialized problems are presented by a number of pollutants whose nuisance value resides primarily in their odor.[20] The wastes from fish packing plants have been dehydrated and used in fertilizer. Aromas produced by the roasting of coffee have been removed through incineration. Recent study and experimentation has resulted in the development of low-cost incinerators within reach economically. The principle of the pebbled stove, forcing gases through a bed of heated pebbles, has been used to purify gases in which there is enough waste material, such as oil, to burn from the heat of the pebbles. Catalytic destruction of the odorous substances has also been employed, utilizing catalytic metallic elements over which the gases are passed at high temperatures. Activated charcoal filters have been used successfully to eliminate persistent odors which defied other means of removal.[21]

AUTOMOBILE, TRUCK AND BUS EXHAUSTS: Among the special problems of great significance to the general problem of air pollution is the nuisance caused by exhausts of automobiles, trucks and buses.[22] The major contaminants produced are carbon monoxide, sulfur compounds, and aldehydes. Carbon monoxide production can be reduced by leaner carburetor settings, and by more efficient engines. Sulfur compounds can be minimized by the use of fuels containing less than 0.3% of sulfur. Efficient water scrubbing devices, feasible for use on trucks and buses, and possibly on automobiles, will remove the aldehydes. Of value for any abatement program are techniques developed by the University of California for the convenient detection, on the road, of smoke pollution due to vehicles, particularly diesel trucks.[23]

RAILROADS: The smoke and cinder nuisance associated with railroads has been greatly reduced in many places, particularly within metropolitan areas, by conversion from coal to diesel. Centrifugal cinder collectors are now being experimented with, in the hope of controlling the emissions from coal burning locomotives.

ORCHARD HEATING: The black smoke of the smudge pot, familiar in orchard and truck farming areas, can be effectively reduced by the installation and proper operation of equipment designed to achieve complete combustion of the fuel used.[24] Los Angeles County is moving ahead with a three-year replacement program for unsatisfactory heaters, begun in the fall of 1950.

REFUSE DISPOSAL: The burning, or other unsatisfactory disposal of refuse, whether by individual citizens in their own backyards, by publicly owned systems, or by privately operated disposal plants, looms large among the sources of contamination in urban territory. A solution to this problem is crucial to the success of any air pollution control program. In many metropolitan areas it will probably be necessary to reduce the backyard burning and other uncontrolled disposal of refuse to a minimum. Substitute disposal methods include the use of high temperature incinerators, sanitary landfills, or other acceptable techniques. In Allegheny County, Pennsylvania, it has been recommended that the municipalities collect refuse and that the county operate incinerators for disposal.[25] Los Angeles County is now examining the possibilities of county collection and disposal of refuse.

DUST STORMS: The control of dust storms presents two distinct problems, one related to irrigated land, the other to non-irrigated land used either for grain or for range.[26] Irrigated land represents the lesser of the problems because it is prone to extensive blowing only during the period of development and satisfactory methods of control have been demonstrated. In contrast, however, it is very difficult to tie down bare, non-irrigated soil during dry weather. Careful farming methods, where employed with foresight, have had a definite mitigating influence on dry-land blowing, and work is now being done on special methods of control. The limitation of grazing can help preserve sufficient protective cover on grasslands.

Summary

AIR POLLUTION is defined as contamination of the atmosphere by smoke, dust, gases, vapors, fumes, and mists. The emission of such substances into the air is the primary cause of pollution, but meteorological and topographical influences are also important. Atmospheric high pressure areas and the associated air inversions are major factors contributing to air pollution, particularly in California.

Health effects of air pollution probably exist, but are not well established; nuisance effects include eye irritation, bad smells, and reduction of visibility; crop and livestock damage from contaminated air have also been observed. The economic loss due to air pollution is considerable.

Air pollution may be eliminated at the source through the use of smokeless fuels or improved burning techniques, collection of contaminants before they are discharged (sometimes these can be sold as by-products), and the redesign of processes to eliminate undesirable emissions.

Tall smoke stacks or systems of "meteorological control" can effect improved dispersal.

Land use and zoning controls can prevent the establishment of undesirable pollution sources in residential areas. Special techniques may be used to combat such problems as odors and smells, automobile and truck exhausts, locomotive emissions, orchard smudge pot smoke, unsatisfactory refuse disposal, and dust storms.

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Reduction of Sulfuric Acid Fumes

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THE post-World War II period has been marked by an intensification of activity in the field of air pollution abatement. Not only has the man on the street become cognizant of air pollution, but industry, also, is realizing more and more that pollution abatement is becoming an investment in good community relations. It is the aim of this paper to describe equipment installed for the sole purpose of air pollution abatement by the du Pont Company as part of a general pollution abatement policy which has already resulted in an investment of $16,900,000 for treatment and recovery facilities, with an additional $5,200,000 expenditure authorized for this purpose.

The production of sulfuric acid mist is characteristic of many chemical and allied processes. Several techniques have been described to accomplish the collection of this material; these include electrostatic precipitators, sonic agglomeration, and venturi or similar higher energy scrubbers. Many of the sources of acid mist are continuous in nature. This presentation is concerned with the suppression of acid mist produced in a batch process at du Pont's Baltimore pigment plant; mist evolution takes place intensely in a short time. It should be pointed out that no product recovery is accomplished with this equipment, the function of which is pollution abatement alone.

Fume Source

THE source of the acid fumes under consideration is the batch attack of ilmenite ore in the production of titanium dioxide pigment. Ilmenite ore, an iron titanium oxide, is added with sulfuric acid to large vessels vented to the atmosphere. To promote the reaction of the ore with the acid, oleum or dilution water is added, either of which produces heat. After "set-off," as this addition is called, the reaction proceeds slowly at first, followed by a sudden increase which is characterized by a temperature rise and the evolution of sulfuric acid, sulfur oxides, and large quantities of steam. As the peak of the reaction passes, a rapid decrease in gas evolution takes place. This is illustrated in Fig. 1. Here the gas flow (in thousands of cubic feet per minute) from the attack vessel is plotted against time (in minutes) after oleum addition to the ore-sulfuric acid mixture in the batch attack vessels. It will be noted that air leakage accounts for a continuous flow of approximately 6000 cu. ft./min. The sulfur oxides and sulfuric acid content of this air is very low. Approximately 45 minutes after "set-off" (oleum addition) a sudden increase in the gas flow rate occurs until the reaction peak is reached. The flow rate at the peak reaches an average of 120,000 cu. ft./min.

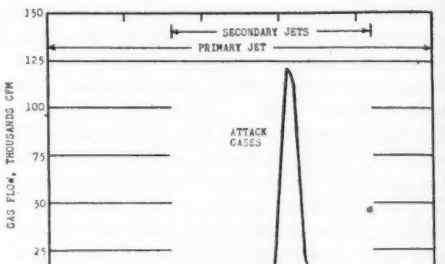

Fig. 1.
Batch attack gas evolution

The gas evolved during this peak period is predominantly steam. Approximately 8000 lbs. of steam and 120 lbs. of sulfuric acid in the form of droplets, mist and acid-wetted ore particles are vented during this five-minute period. In addition, 36 lbs. of SO_2, 8 lbs. of H_2S, and 76 lbs. of SO_3 are produced during the course of a typical attack.

It can be seen that any fume abatement

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system installed must have the following characteristics:

1. Ease of intermittent operation.
2. Ability to handle large peak gas loads of air and steam for short periods of time.
3. Removal of sulfuric acid mist and droplets from the gas stream.
4. Prevention of the creation of water pollution in abating air pollution.

Fume Quencher System

THE fume quencher system designed and installed for the collection of the batch attack fumes center about a 72-in. steel-plate, rubber-lined Schutte-Koerting jet scrubber. The scrubber and the auxiliary equipment are shown in Fig. 2. This has been simplified for the sake of clarity.

The stack shown at the right represents that on each attack vessel. There are several such stacks, made of wood and all served by the same fume scrubbing system. The inlet ducts, about 7 ft. in diameter, actually make up a rubber-lined steel manifold system connecting each vessel stack to the fume quencher. Each duct is equipped with a rubber-coated hydraulically operated damper so one stack at a time can be connected to the fume scrubbing system.

The heart of the fume quencher is the jet system consisting of primary and secondary jets. A 1000-g.p.m., 100-hp. pump continuously supplies water to the primary jet throughout the batch attack cycle. The primary jet is about 3 in. in diameter. This is sufficient to quench the small quantities of sulfuric acid fumes and ore dust given off during the initial and final stages of the attack. Surrounding the primary jet are 72 secondary jets, each ¾ in. in diameter, supplied by an 8000-g.p.m., 300-hp. pump.

Both jets discharge downward into a 15,000-gallon tank. The water from this tank may flow out through the overflow valve A and/or may be recirculated through the 8000-g.p.m. pump to the secondary jets.

The pH of the recirculated water is controlled to prevent equipment corrosion and prevent subsequent discharge of acid water, creating a water pollution problem.

The cleaned gases entrained and scrubbed by the jets leave the system through the exit stack.

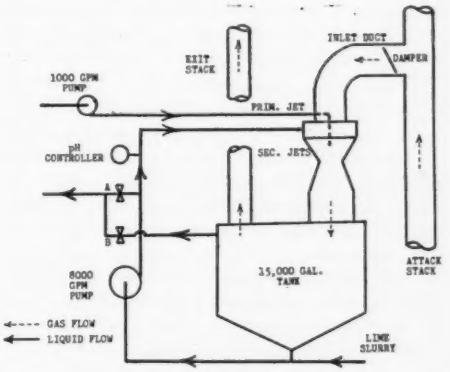

Fig. 2.
Schematic diagram of fume eliminator system

Operational Sequence

THE fume quencher cycle begins with a full 15,000-gallon tank and the damper opened to the batch attack stack in use. The primary jet is used for the initial stages of the process step when acid and ore are added to the attack vessel. The small quantities of dust and fumes produced at this stage are satisfactorily handled. The water thus delivered to the 15,000-gallon tank overflows through valve A.

Referring to Fig. 1, it will be noted that the secondary jets are started on the average of about seven to 10 minutes before the violent evolution of steam and acid mist. The system was designed to handle a normal peak of 120,000 cu. ft. of stack gas per minute.

The system depends primarily on condensation of steam in the jets, thus creating a vacuum to draw the fumes out of the stack. Thus the initial gas evolution must first fill up the system in order to prime the jet quencher. During this time, gas escapes from the main stack for 10 to 25 seconds until steam condensation proceeds at a sufficient rate and the jets take hold.

With one damper open both jets produce a vacuum of ¼ to ½ in. of water in the duct above the jets. With both jets in operation, 9,000 g.p.m. of water enter the tank through the jet. It is worth noting in passing that this rate of water would supply a city of about 85,000 persons.

The continuous scrubbing of sulfuric acid from the stack gas by the recirculating water would soon lead to corrosive conditions. For this reason the pH is recorded and regulated between 6.0 and 6.5 with a lime slurry manually added ahead of the 8000-g.p.m. pump. Approximately 150 lbs. of lime is required for each attack. A secondary benefit is the elimination of the discharge of acid water from the quencher.

Upon completion of an attack, the 15,000-gallon tank is emptied through valve B at infrequent intervals, more often in the summer. The tank is then refilled with the 1000-g.p.m. pump in preparation for the next batch attack. There are two principal reasons for emptying this tank. The condensation of steam in the jet is accomplished best by cold water. The hot gases from an attack heat the recirculating tank water so that it must be replaced with cold water to insure proper jet quenching action. The water temperature in the tank rises about 30°F during a typical attack. The corresponding stack gas temperatures will rise from 80-90°F to as high as 300°F at the reaction peak.

The second reason for refilling the tank is to prevent the build-up of calcium sulfate from the reaction of lime and the sulfuric acid collected. This would eventually lead to scaling and sludge build-up with ensuing difficulties.

The gas which leaves the exit stack is primarily saturated air plus very minor amounts of acidic constituents. There appears to be no carry-over of acid mist or acid wetted ore particles.

Operational Precautions

THERE are several principal precautions required for satisfactory operation of this equipment. The system must be well sealed to prevent in-leakage of air resulting in an overload of the scrubber. It is important that the dampers to the inactive stacks be well closed. This offers some difficulty since acid-wetted ore particles accumulate in the scrubber duct-work and are especially troublesome around the damper seats. These accumulations are removed by hosing down the dampers and ducts at frequent intervals.

Sand and gravel brought into the system from the water supply occasionally plug the smaller secondary jet nozzles, hindering the scrubber operation. A screening system to overcome this difficulty is now being investigated.

Operational and maintenance inspections include semiannual checks on the pump capacities and the temperature recorder, monthly inspection of the pH recorder, weekly examination of damper closing and duct cleaning, weekly inspection of the jet nozzles for proper flow during pump operation, and daily draining of the line from the bottom of the 15,000-gallon tank for the removal of settled solids.

Summation

IN ONE step of the process for the manufacture of titanium dioxide pigment, large quantities of acidic gases are released in a very short period of time. These gases contain sulfuric acid mist and droplets, some SO_3 and SO_2, and large quantities of steam. A Schutte-Koerting jet scrubber was installed to scrub the sulfuric acid constituents from the attack gases, the peak scrubber operation being timed to the period of maximum gas evolution. The water scrubbing medium is neutralized to prevent corrosion and the creation of a water pollution problem. The equipment, with proper operational and maintenance precautions, has operated satisfactorily, resulting in an effluent consisting of saturated air with minor amounts of acidic constituents with no carry-over of acid mist or acid-wetted ore particles.

Health Hazards Associated with Use of Airplanes for Dusting Crops with Parathion

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INSECTICIDES for the control of agricultural insect pests by dusting and spraying have been used for many years. At first, hand application was practiced. Later labor-saving mechanical application from self-propelled or tractor-drawn rigs increased not only the effectiveness of the application but also the acreage which could be covered in a given time. Now aircraft are employed to increase the effectiveness further by permitting more frequent and greater acreage coverage.

The use of airplanes for insect control is not new. As early as 1923, airplanes were used for control of both larvae and adult mosquitoes by W. V. King, of the Federal Bureau of Entomology and Plant Quarantine. Paris green and other arsenicals have since been applied extensively from aircraft by the Tennessee Valley Authority and other agencies. DDT spray for mosquito control was applied over large areas by the Army in 1943. With the advent of many new insecticides, much experimentation took place with methods and equipment for dispensing both dust and spray materials. The earlier experimental work in this field is well described in the U.S. Department of Agriculture Miscellaneous Bulletin No. 606, August, 1946.

Both fixed-wing planes and helicopters are being used today for the application of insecticides and both have found favor among the applicators. The helicopter no doubt is advantageous for use in small areas not readily accessible with the conventional type aircraft.

In California, most aircraft insecticide application is through the medium of dusting, possibly due to the economics of the material and the potentially better coverage.

Since 1940, when the U.S. Public Health Service published its findings of the effect of lead arsenate on orchardists and consumers of apples, many new insecticides far more virulent have been developed. Parathion is the product of a search, stimulated by the discovery of DDT, for organic insecticides of even greater potency. HETP (hexaethyl tetraphosphate), and TEPP (tetraethyl pyrophosphate), have been developed and still are in use, but parathion (diethyl nitrophenyl thiophosphate) has properties not possessed by the other organic phosphates. These properties have popularized it to such an extent that it is being used extensively.

Parathion is very toxic to warm-blooded animals and there have been various reports in the news and in the literature of its use having resulted in several fatalities and a number of cases of illness, some among aircraft pilots.

The Bureau of Adult Health, California State Department of Public Health, became extremely interested from an industrial hygiene point of view in the potential hazards to pilots dusting crops with parathion. A study was initiated among airplane crop dusters who used parathion to determine, if possible, by correlation with medical data on the men, how serious the exposure to pilots might be.

Parathion, under the restrictions of the Bureau of Chemistry, California State Department of Agriculture, now reaches the applicator as a wettable powder containing parathion 15% (25% is also available) and as dusts containing 1% or 2% parathion. The vapor pressure of parathion is low, although it is still somewhat volatile. It is claimed that parathion does not remain on foliage in the field longer than a few weeks and therefore does not constitute a residue problem. It may, however, prove dangerous to irrigators and others who must enter the field soon after spraying or dusting operations. Recently 16 out of some 24 workers thinning vines and grapes in a vineyard in California were

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made ill from the residue even though they did not enter the field until approximately two weeks after application of the parathion as a wetted powder.

Our Bureau of Adult Health studies included the operations of several different companies using planes for dusting. Atmospheric samples were secured with midget impingers using ethyl alcohol as the collecting medium. Although samples were taken at the normal breathing zone of the pilot, they did not represent his actual air breathed since they were obtained outside his gas mask. The concentration of parathion was determined using the Averill spectrophotometric method of analysis. (*Analytical Chemistry,* August, 1948.) Since the planes were not equipped for passengers an automatic sampling device was constructed for sampling during the dusting run. This device is described in the March, 1951, issue of *Industrial Hygiene Newsletter.*

Fig. 1 shows the pilot loading a bag of parathion 1% mixed with 5% DDT and 25% sulfur. The hopper is located directly in front of the pilot's compartment and during loading operations, dust may filter and blow into the area where the pilot later may come in contact with it. Note that the approved full face gas mask is connected to an organic vapor and acid gas absorption cannister. Gloves, coveralls, neckpiece, and full head covering are also worn for protection. Both the pilot and swamper load the hopper and both are similarly protected with full face mask and protective clothing. In this study the average loading was 20-24 bags of 50-pounds capacity. Loading was accomplished in about four minutes and the pilot dusted the load in about 25 minutes. A pilot could apply from five to six loads per day for a five-day week if there were a demand for the insecticide.

Fig. 2 shows the dispensing unit under the fuselage at the forward edge of the wing. The motor for operating the feed mechanism is seen under the wing on the right side of the plane.

Fig. 3 shows the plane being flown at very low level to spread the parathion-DDT-sulfur mixture on a field of potatoes. Early morning—5:00 to 8:00 A.M.—is the best dusting time because wind velocity is then minimum. When wind velocity ex-

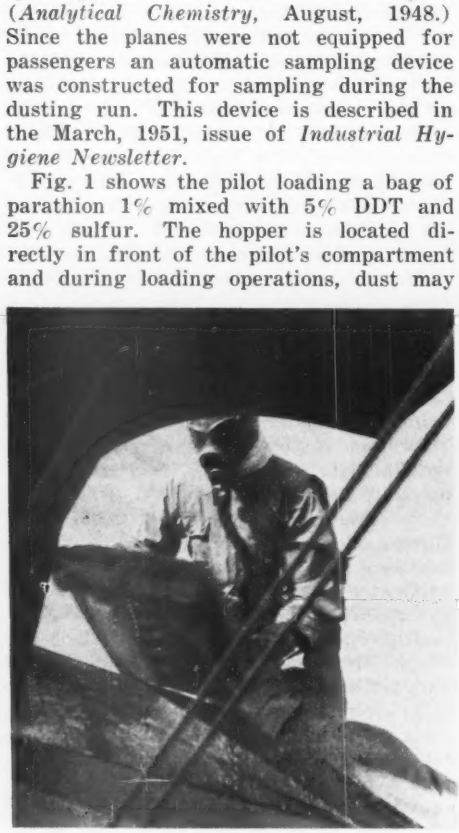

Fig. 1.
Loading a 50 pound bag of parathion, DDT, and sulphur insecticide mixture into hopper of an airplane for dusting.

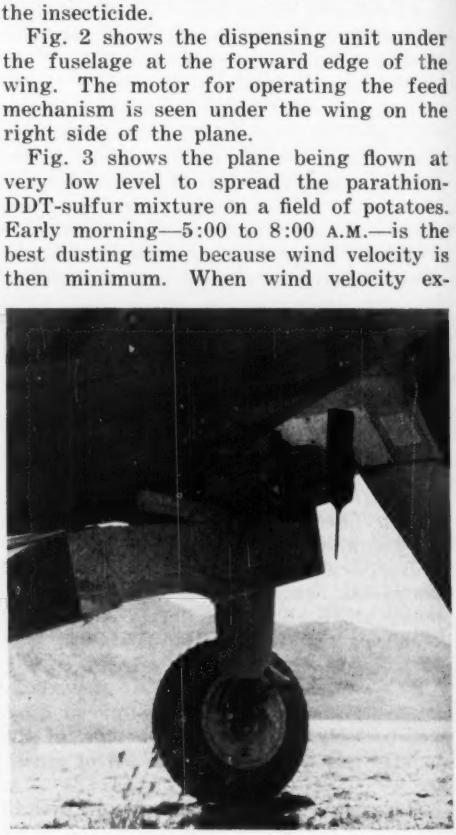

Fig. 2.
Dust dispensing unit located under fuselage at forward edge of wing. Motorized feed mechanism is seen to the right under wing of plane.

ceeds five miles an hour the effectiveness of the dusting is greatly diminished.

Blood cholinesterase activity levels were, with few exceptions, made at 14-day intervals. Pilots and swampers were taken to Kern County Hospital where physicians of the County Health Department drew venous blood samples and placed them in citrated tubes supplied by Bureau of Adult Health. In the hospital laboratory the tubes were centrifuged, plasma drawn off and the cells washed. The samples were then packed in ice and taken to Bureau of Adult Health laboratories in Los Angeles. Cholinesterase activity levels were determined for both plasma and red cells using the method described by Michel in the *Journal of Laboratory and Clinical Medicine*, November, 1949. Owing to technical difficulties in red cell determinations, the results on red cells were not considered accurate and were not used in this study. In order to compare results with previous work using the slower titration method of Steadman (dsecribed in Volume 27, 1933, of the *Biochemical Journal*) a conversion factor was used and the figures in Table I represent titration units (ml. .02 N NaOH required to neutralize the acetic acid liberated in 20 minutes by the cholinesterase acetylcholine reaction in 1 ml. of plasma).

Since but 10 pilots and three swampers stayed on the job through the entire test from June 23 to August 30, 1950, only data on these men are presented (Table I).

The exposures indicated are not the amounts of parathion actually absorbed or breathed but rather are those to which the person would have been subjected if no protection had been provided.

Fig. 3.
Low level flying to apply parathion, DDT, sulphur mixture to a field of potatoes.

During the test series only one man, Mr. S, developed symptoms apparently due to parathion. He experienced dizziness, abdominal cramps, nausea and headache, which, with vomiting and pupil contraction, are typical symptoms of organic phosphate

TABLE I.
SEASONAL EXPOSURE TO PARATHION AND PLASMA ACTIVITY—JUNE 23, 1950, TO AUGUST 30, 1950

	Total Exposure Time Hours		Total Exposure Mg. Parathion			Plasma		
Pilots	Dusting	Loading	Dusting	Loading	Total	Minimum	Maximum	Average
°S	58	4.0	11.6	36.8	48.4	1.8	5.4	3.7
R	20	1.3	4.0	12.2	16.2	2.1	3.1	2.6
L	81	5.4	16.2	50.0	66.2	2.0	3.4	2.6
°C	189	12.4	37.8	114.0	151.8	2.4	4.1	3.2
T	126	8.4	25.2	77.4	102.6	3.6	4.9	4.3
B	60	4.0	12.0	36.8	48.8	4.1	5.4	4.9
S	95	6.2	19.2	57.2	76.4	2.2	3.6	2.9
J	3	—	—	—	—	3.4	3.6	3.5
T	62	4.0	12.0	36.8	48.8	3.0	3.1	3.0
F	3	—	—	—	—	3.4	3.9	3.7
	Average Exposure—Mg/hr.		.2	9.2	—	—	—	—
Swampers								
B	—	14.0	—	129.0	129.0	2.9	3.5	3.1
J	—	12.4	—	114.0	114.0	2.6	4.7	3.6
H	—	2.0	—	18.4	18.4	2.5	3.6	2.9

poisoning. S performed 12 hours of crop dusting and about a half hour of loading during the two weeks prior to the illness. His plasma cholinesterase activity dropped to 1.8 compared to his maximum of 5.4. Through our suggestion, he discontinued dusting with parathion for the following six weeks. Although he remained on the job applying other chemicals, his cholinesterase activity returned to its former level. In contrast to this man's experience, other pilots handled from as much to three times as much parathion dust without physical symptoms of poisoning or reduction in cholinesterase activity. Presumably some momentary carelessness caused the excessive exposure of S. We know that his plane cockpit and fuselage contained large quantities of parathion capable of vaporization in the sun's heat, a dangerous situation for a pilot even when he wears a protective mask.

None of the other pilots appeared to be affected by parathion exposure. Mr. C, who had the most exposure time for the season with 189 hours of dusting and 12½ hours of loading, had little change in blood cholinesterase activity. We noted that Mr. C was very cautious in avoiding exposure to parathion. The other pilots, who had half to two-thirds the seasonal exposure of Mr. C, also exhibited no effects from their activity.

The seasonal parathion exposure of swampers is not so large as that of pilots, since they are engaged in loading only and not in dusting. None of the swampers observed through the season experienced any abnormally large reduction in cholinesterase activity of their blood. Probably the greatest danger to the youthful swampers exists in their lack of proper caution due to inexperience and over-optimism. The large labor turnover for swampers results in an inflow of untrained and possibly over-confident ground crews.

If the cholinesterase activity of a person working with parathion shows a continual decrease, it would appear that he is being exposed to parathion even though no symptoms of poisoning are apparent. If his cholinesterase activity drops appreciably, it would be wise to prohibit further exposure until it has risen to his normal range. The range of plasma activities in this series seems to be from 2.0 to 5.0 titration units.

Periodic determination of blood cholinesterase activity levels is considered to be a valuable basis for evaluating the efficiency of procedural measures and for recommending temporary change of work for individuals regularly handling organic phosphate materials when levels become dangerously low. Its more general adoption has been hampered by the high cost of laboratory work, the lack of adequate preventive medical attention, the hesitation of individuals to have blood samples taken, and the difficulty of shipping specimens to laboratories prepared to make the determinations. Although a single determination considered by itself does not mean a great deal, the individual normal level value is important for comparative purposes and should be ascertained.

Since the atmospheric samples were not of the actual air breathed by the pilots and swampers, we did not make a definite correlation between actual exposures and biological effects; therefore, we are unable at this time to shed any further light on the amount of parathion which may possibly be inhaled without damage. We do know that symptoms have occurred following absorption of very small amounts of parathion, probably considerably less than 5 milligrams. There is some evidence presented in the literature that repeated doses, too small to cause noticeable symptoms, probably will build up a systemic condition so that one more such dose will cause severe symptoms. With our present knowledge, therefore, it seems that the only safe procedure would be to keep exposure to this substance at an absolute minimum.

In order to do this, certain individual procedures are recommended. The following summarizes the suggestions, in addition to the precautions listed on the package labels, which are offered by our Bureau for the protection of pilots:

CLOTHING: The following items of protective clothing are recommended as being both practical and protective:

Helmet—Plain canvas. Collects relatively little dust and can be laundered.

Shirt—Wool fleece sweat shirt. Wash-

able and tends to keep dust from blowing up arms or down neck.

Scarf—Flannel. Washable and comfortable. Should be neck-wrapped and lapped over the sweat shirt.

Cover-alls—One-piece birdcloth with zipper and buttoned flap over zipper. (The flap and buttons will probably have to be added after purchase.) The pocket slashes should be sewed up, and snug fitting elastic or easily adjustable straps should be placed around the trouser bottoms. These modifications are to keep dust from entering through the zipper opening, pocket slashes or trouser bottoms. Trousers may be tucked into closely fastened footgear or preferably worn outside if the bottoms fit snugly.

Gloves—Canvas gloves with elastic wrists or gauntlets which cover the wrists of the cover-alls. Canvas gloves are not as good protection as natural rubber gloves and are recommended only because they can be tolerated while flying and because they can be laundered after each use.

Footgear—Rubber-covered galoshes are recommended because they catch little dust and can be worn over street shoes. High leather field boots may be worn if thoroughly cleaned immediately after removal of cover-alls.

PUTTING ON PROTECTIVE CLOTHING: All the protective clothing, including helmet, gloves and galoshes, should be put on and fastened before approaching the dusty area. The protective clothing may be put on over the ordinary clothing worn to work but should not be worn in place of ordinary clothing unless such is brought along for a change immediately after exposure has ceased.

REMOVING PROTECTIVE CLOTHING: As soon as dusting or spraying has been completed, the pilot should be thoroughly brushed down by the swamper standing to windward of him; if not by the swamper, then by himself, being careful not to inhale dust. Next the protective clothing should be removed, all except the galoshes placed in a clean laundry bag, any remaining dust removed from galoshes and the outfit placed in his car. Finally the pilot washes his hands.

LAUNDRY: The laundry bag containing the protective clothing should be placed upside down in a washing machine, the bag removed from the clothing and both bag and clothing washed with plenty of warm soapy water and thoroughly rinsed. This must be done after each wearing of protective clothing.

WASHING AND BATHING: The feeder truck should be equipped with a water tank of at least 10-gallon capacity with a spring faucet projecting over the side of the truck. If the pilot wants to smoke, make notes in his log book, or for other reason remove his gloves during operations, he should first be brushed down, then wash his hands using plenty of water, followed by lotion if he so desires. Hands should be air dried or dried with a clean towel from his car or other dust-free place, never wiped on clothing or other dusty material. Immediately after removal of the protective clothing at the end of the dusting activity, the hands should be washed as described and a thorough shower taken as soon as practicable, at least the first thing on arriving at home.

MAKING THE PLANE SAFE: An airtight baffle (bulkhead) should be provided across the fuselage behind the cockpit to prevent the entrance of dust through the tail wheel insert.

If there is no windshield a fairing should be fixed between the hopper and the cockpit to prevent the lodgement of dust during loading which will later blow into the cockpit.

The hopper cover should have a sponge-rubber or felt gasket and should be closed as soon as filling is completed.

FILLING THE HOPPER: Leave propeller spinning so as quickly to remove dusty atmosphere from the breathing zone.

Handle sacks so as to spill the least possible amount of dust and yet fill the hopper quickly.

Use a shovel for packing dust into the hopper, never the hands.

Replace and fasten the hopper cover as soon as loading is completed.

Remove any dust remaining around the hopper or cockpit and let the prop wash carry it away.

RESPIRATOR: A full facepiece canister type respirator should be worn at all times during dusting, loading of the hopper and

at other times when there is risk of inhalation of dust. A half mask and separate goggles are unsatisfactory because they will not remain leakproof and may leave part of the face exposed.

The army-type oxygen mask is recommended for the facepiece because of its comfort and easy fit. The Army officer's gas mask facepiece is also satisfactory. The rubber air exhaust of the facepiece should be covered with a shield to block head-on wind.

The air intake for the canister should be from outside the cockpit, preferably near the end of the wing with the intake tube fixed inside the wing. The spring cutoff as supplied with the Army oxygen mask makes an excellent connection between the air supply tube and the canister because of the ease with which it can be disconnected to make the canister portable during loading and while out of the cockpit.

GENERAL PRECAUTIONS: Cars should not be parked where dust will get on them.

The propeller should be left spinning during loading operations and while the pilot is being brushed down in order to blow dust away from both pilot and swamper.

Each time the pilot gets out of the cockpit he should stand in the prop wash and be brushed down, preferably by the swamper using a long-handled broom.

The pilot should be careful to stand down wind to the swamper or anyone less dusty than himself.

While this paper describes dusting with parathion by aircraft, the precautionary measures suggested are just as applicable to any other toxic insecticide. Strict adherence to recognized . safeguards which are published and available to all pilots and swampers is necessary for positive protection. If these safeguards are followed, there should be no fear of parathion or any other insecticide poisoning in the use of airplanes for dusting crops.

Summary and Conclusions

The use of aircraft for applying insecticide to crops is described with particular reference to California experience when dusting with parathion. Atmospheric samples, although secured at the normal breathing zone, represented only potential exposures since by necessity they were obtained outside of the gas mask facepiece. Blood cholinesterase activity levels were made at fifteen day intervals on both pilots and swampers. Methods used and results of these tests are described. Individual safe practices are given.

Periodic determination of cholinesterase activity levels is considered to be a valuable basis for evaluating the efficiency of protection measures and for recommending temporary change in work status. Normal cholinesterase activity level should be determined for comparative purposes. It is possible, from evidence to date, that repeated small doses of parathion may build up a systemic condition so that one more dose will cause severe symptoms. Reduction of exposure to the absolute minimum by process control and individual safe practices is necessary.

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Mercury Vapor Hazards in the University Laboratories

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THE PURPOSE of this paper is to report an investigation of the potential health hazard of mercury vapor in teaching and research laboratories on the Berkeley campus of the University of California. Although the study included laboratories in which spilled mercury was in evidence on bench tops and floors, in only one was it found necessary to take immediate steps toward control of the mercury vapor hazard. The findings of the investigation and the control measures applied to the laboratory with the excessive contamination are discussed and summarized in this report.

Literature

EACH use of mercury must be individually considered when developing means for control of mercury contamination. There is no over-all formula to prevent exposure to hazardous concentrations of mercury vapor, and only general rules developed in former studies can be followed in setting up techniques for control. Several important studies have been made to evaluate the effects of mercury poisoning and determine its source of contamination in certain of its uses. Two outstanding studies of mercurialism were made by the U.S. Public Health Service concerning mercury exposure in the felt hat industry, where many workers were being disabled by mercury poisoning due to the use of mercury compounds in the carrotting process (application of a mercury solution to the felt to make it tenacious).[1,2]

In the study, "Mercurialism and its Control in the Felt Hat Industry,"[2] the Public Health Service established the present maximum allowable concentration of 1 milligram of mercury per 10 cubic meters of air. Owing to recent developments, mercury poisoning in the felt hat industry is no longer a hazard. By voluntary action on the part of the several felt hat manufacturers, mercury has been replaced by a non-toxic carrotting agent.

However, mercury is still being used in large quantities in laboratories and in certain industrial processes. It is obvious that if mercury could be replaced in all its uses, the difficulties concerned with the control of its hazard would be eliminated. In many of these processes, however, there are no efficient substitutes for mercury. For example, laboratories find mercury an almost indispensable material in metering instruments, as a displacing fluid, and in certain chemical and physical analyses. Mercury has properties which make it a versatile tool in the laboratory.

The U.S. Bureau of Mines describes an investigation of the "Hazard of Mercury Vapor in Analytical Petroleum Laboratories."[3] The Public Health Service discusses a study it made in "Hazard of Mercury Vapor in Scientific Laboratories."[4] These two studies, the first using a Nordlander selenium sulphide mercury vapor detector and the second using an ultraviolet mercury vapor indicator, led to similar conclusions and recommendations. Both studies demonstrated several facts which are important in evaluating a possible mercury vapor hazard: (1) that wherever there is good ventilation there will generally be a low mercury vapor concentration, even though considerable mercury may be in evidence; (2) that oxidation, dust, and oil film cause a substantial reduction in the partial pressure of mercury vapor; and (3) that microscopic droplets of mercury, often impregnated in wood tables or floors or in porous concrete floors, furnish the major portion of mercury vapor tension in the room air. Mercury globules large enough to be visible are negligible, comparatively, in their vapor-producing ability. The present study of the several laboratories investigated on the University of California campus confirmed these observations.

Description of Equipment

AN ULTRA-VIOLET photometer of the type developed by T. T. Woodson, of the

General Electric Company, was used in making the investigation in the University of California laboratories. The ultra-violet photometer is a direct-reading device which depends upon the effect of an ultra-violet lamp on a photoelectric cell. The lamp and the photoelectric cell are located at the opposite ends of a chamber. A uniform flow of air is drawn through the chamber by a blower. If mercury vapor is present in the air, the photoelectric cell will show less response to the ultra-violet lamp because less light of the proper wave length is allowed to reach the cell. A reduction in the impressed voltage of the phototube throws a bridge out of balance. This unbalance is indicated on a milliammeter. The ammeter reading is then compared to a calibration curve. Mercury vapor contamination can be determined from the curve as milligrams per cubic meter of air. An important feature of the Woodson detector is that it is sensitive to low concentrations of mercury vapor. Concentrations as low as 10-20 micrograms of mercury per cubic meter of air can be detected. Since liquid mercury has a vapor pressure at room temperature of .0014 mm, the possible concentrations of mercury vapor in laboratories are easily determined.

The findings in the several laboratories studied are summarized in Table I.

The conditions as regards mercury vapor contamination which are summarized in Table I were determined in a preliminary type of investigation. No attempt was made to study the possibility of mercury vapor hazard in the individual rooms of the laboratories under varying atmospheric conditions. The investigation was conducted during a normal warm autumn period with an air temperature of approximately 70°F and moderate air movement. This would approximate an average atmospheric condition in the laboratories.

Several significant facts can be gathered from the table:

1. Wherever there was any appreciable ventilation, the vapor detector showed either no mercury vapor present or a very low concentration.

2. In areas in which the temperature was above normal, as under, or near, a radiator, the detector indicated higher than the general room mercury vapor concentration.

3. Even when there were appreciable visible droplets of mercury in evidence as on table tops and floors, where the ventilation was good the mercury vapor concentration was low.

4. The detector gave high readings for mercury vapor immediately over sink traps in laboratories where mercury had evidently been washed down the drain and had amalgamated with the cast iron or brass of the water trap.

The factor of oxidation, oil film, and dust no doubt aided in keeping the mercury vapor concentration low in all of the laboratories including those in which visible mercury droplets were present. Also it is

TABLE I.
CONCENTRATION OF MERCURY VAPOR FOUND IN UNIVERSITY OF CALIFORNIA LABORATORIES

Dept.	Room	Conc. mg/m³	Location and Test Conditions
Physics	316-344	.03	General room air at breathing zone—ventilation good.
		.12	Floor under radiator.
		.02	On floor and table tops.
	12-209, 326	—	Negligible contamination.
Chemistry	202	.02	General room air at breathing zone—ventilation good.
		.24	Table top—spilled mercury in evidence.
		.10	Sink drains—spilled mercury in sink.
	203	—	No appreciable mercury vapor at breathing zone.
		3.1	Sink drain.
	314	.02	General room air at breathing zone.
		.13	Sink — spilled mercury in evidence.
	258	—	No appreciable contamination at breathing zone.
		.05-.12	Adjacent to floor drain covers.
	101, 321	—	Negligible contamination.
Biochemistry	1510	.03	General room air at breathing zone—ventilation good.
		.22-3.2	Sink drains.
	1516	.03-.06	General room air at breathing zone—ventilation fair.
		.12	Rear floor—some areas.
		.33	Sink trap.
		.04	Table top—spilled mercury in evidence.
	1573	.02	General room air at breathing zone—ventilation fair.
		.10	Sink trap.
	1519-1560, 5521	—	Negligible contamination.
Research	(1)	.10	Floor level—ventilation fair —mercury in evidence.
	(6)	.10	Floor level—ventilation good.
		—	General room air at breathing zone—ventilation good.
	(2)-(5)	—	No appreciable mercury vapor detected.

TABLE II.
TESTS FOR MERCURY VAPOR CONTAMINATION IN THE PETROLEUM LABORATORY
HEARST MINING BUILDING, UNIVERSITY OF CALIFORNIA

Date	No.	Time	Temp. °F	Room 238 N.E. Cor.* mg/m³	Room 238 N.E. Cor.** mg/m³	Room 238-A S.E. Cor.* mg/m³	Room 238-A S.E. Cor.** mg/m³	Test conditions
10/24/49	1.	12:20 pm	72	0.13	0.19	0.11	0.19	Ventilation poor
	2.	1:46 pm	73	0.11	0.16	0.15		Ventilation fair
	3.	3:51 pm	68	0.03	0.06	0.04		Considerable air movement
10/25/49	4.	8:10 am	70	0.04	0.15	0.03	0.04	Ventilation fair
11/25/49	1.	8:45 am	67	0.10	0.12	0.16	0.24	Ventilation poor
	2.	10:20 am	69	0.21	0.25	0.30	0.43-0.60	Ventilation fair
	3.	1:15 pm	70	0.11	0.33-0.42	0.12	0.30-0.43	Ventilation fair
	4.	3:05 pm	72	0.12	0.25	0.20	0.37-0.56	Ventilation fair

*Breathing zone
**Floor level

evident that mercury vapor concentration in room air is a function of mercury surface available for vaporization and of air motion.

Petroleum Laboratory Investigation

A PRELIMINARY investigation in the petroleum laboratory indicated a significant mercury vapor concentration in at least two areas, and it was decided to make a more thorough study of the conditions in this laboratory. The two areas which showed significant mercury vapor contamination were in Room 238 and the adjacent 238-A, Hearst Mining Building. These areas in the respective rooms were later used as test areas. These were to be periodically tested throughout a working day to determine possible changes in mercury vapor concentration according to the varying atmospheric factors of temperature and ventilation.

Mercury had been spilled on the floors, and was in particular evidence in Room 238. Not fully realizing the possibility of a hazard, the laboratory technicians had made little effort to eliminate these sources of contamination, and the mercury as minute droplets had considerably impregnated the concrete floor.

For the purposes of the test the laboratory was closed tight for an entire weekend in order to build up a significant mercury vapor concentration in the test rooms. On Monday morning, October 24, 1949, the Woodson vapor detector was brought in and periodic sampling was started. Table II gives the results of this test. Because the test showed a definite hazard (at several times during the day, the vapor detector indicated above the maximum allowable mercury vapor concentration at the breathing zone), the technicians in the laboratory expressed concern and it was decided that the spilled mercury should be cleaned up as soon as possible.

The technicians themselves carried out a very thorough cleanup of all the visible mercury, using a vacuum cleaner. Following this, the laboratory was closed for another weekend. The Woodson detector was again brought in on November 25, 1949, and another test made. Table II gives the results of this test. The last test indicated a mercury vapor concentration substantially higher than the previous one, showing that although all visible mercury had been eliminated a considerable amount of dust and oil film had also been removed, exposing many of the minute particles of mercury which had impregnated the concrete floor. This was to be expected, considering findings in previous studies.

The test area of Room 238-A (about 10 feet square) was washed down with a solution of sodium polysulphide,* in order to measure the chemical's effectiveness in lowering mercury vapor concentration. A test was then made, with the result that in Room 238-A there was no appreciable difference between the concentrations of mercury vapor at breathing zone and at floor level, as indicated in A, Table III. This seemed to indicate that the sodium polysulphide was effective, but it was decided to let it stand for a few days to determine if the control measure would remain as effective.

TABLE III.
FOLLOW-UP TESTS FOR MERCURY VAPOR CONCENTRATION IN THE PETROLEUM LABORATORY, HEARST MINING BUILDING, UNIVERSITY OF CALIFORNIA, BERKELEY

Test	Room	Conc. Mg/m³	Level of Test
A.	238	0.08	Breathing zone
		0.15	Floor level
	238-A	0.04-0.06	Breathing zone
		0.04-0.06	Floor level
B.	238	0.10	Breathing zone
		0.13	Floor level
	238-A	0.10-0.12	Breathing zone
		0.10-0.12	Floor level
C.	238	0.01	Breathing zone
		0.02	Floor level
	238-A	0.01	Breathing zone
		0.02	Floor level
D.	238	0.02	Breathing zone
		0.03	Floor level
	238-A	0.02	Breathing zone
		0.03	Floor level

Three days later a further test was made under similar ventilation conditions. The results of this test are listed in B, Table III, and seemed to indicate that the sodium polysulphide had remained effective. Following this it was decided to wash down the entire floors of both rooms, 238 and 238-A, with the chemical. Then a final test was made, the results of which are indicated in C, Table III. Several benches were checked where mercury had been spilled, and the mercury vapor concentration was found to be 0.04 milligrams per cubic meter of air. This, with the other findings, indicated that the porous impregnated floor provided the bulk of the mercury vapor, and that the sodium polysulphide substantially eliminated the hazard.

Approximately two months later the Woodson detector was again brought into the laboratory and a check made to determine if the sodium polysulphide had remained as effective as in the preceding test. The results of this test are listed in D, Table III. The temperature on the day of the latter test was higher than normal, possibly accounting for the slightly higher vapor indicator's readings. This test would seem to indicate an efficient method for elimination of mercury vapor hazard.

Summary

TO SUMMARIZE what has been found in these investigations, the following points are noted:

1. Ventilation is a major factor in keeping the mercury vapor concentration low.

2. Oil, dust, and oxidation tend to suppress the vaporization of mercury.

3. When the suppressing agents are removed, as in vacuum cleaning, the vapor concentration will substantially rise.

4. When spilled mercury is not immediately removed, it will break down into smaller and smaller particles until they are of such size as to enable them to permeate the pores of wood and concrete.

5. Where mercury has permeated porous floors, the vaporization of the tiny globules can be eliminated or largely suppressed by the application of a solution such as sodium polysulphide.

*Calcium polysulphide was used to control mercury vapor in the manufacture of dry cell batteries.[5] The process of using an alkaline polysulphide in the control of mercury vapor was developed by the late Professor Merle Randall, of the Chemistry Department, University of California, Berkeley. It was first used as a spray to reduce the mercury vapor hazard in quicksilver mines and was very effective. This method has since been extended to other areas where mercury presents a problem.[6]

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Stray X-rays from Electron Beam Instruments and Some Biological Implications

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RECENT investigations have established the existence of a number of stray radiation sources of interest to the industrial hygienist.[1] It would appear, as will be indicated later, that electron-beam instruments of many types, operating with moderate to high accelerating potentials, need to be considered as potential or actual sources of stray x-radiation. Since an increasing number of such instruments are to be found in industry, including industrial oscillographs, electron microscopes, and the like, it should be clear that account needs to be taken of the problem. The personnel involved will be not only the technicians and operators but also others in the general vicinity or in adjoining rooms.

The general effects of stray x-radiation on man have been adequately reported in the literature. It might be mentioned, as a matter of interest, that certain of the harmful effects of x-radiation make their appearance after the lapse of considerable time, in contrast to the more rapid effects of some of the other industrial hazards.

Certain similarities between x-ray tubes and electron beam instruments need to be borne in mind. In both cases we normally have an evacuated tube, a source of electrons, beam-forming accessories, and the use of an accelerating potential. In the x-ray tube the accelerated beam is caused to impinge upon a metallic target, usually tungsten, while in a typical electron-beam instrument such as a cathode-ray tube, the "target" is the fluorescent screen.

Localization of Stray X-Ray Sources

I. INDUSTRIAL OSCILLOGRAPH: In the course of a survey of an industrial cathode-ray oscillograph it was noted that the radiation level in the entire area surrounding the instrument was many times normal background. The preliminary survey for the existence of stray x-rays was made with a Victoreen survey meter. This instrument, while calibrated for gamma rays from radium, is perfectly usable for stray x-radiation surveys where exact quantitative data are not required.

With the use of the survey meter, it was determined that the heaviest radiation was emerging from the vicinity of the cathode or electron gun area, specifically from several rectangular openings in the metal housing surrounding the cathode area, and from the glass wall of the dis-

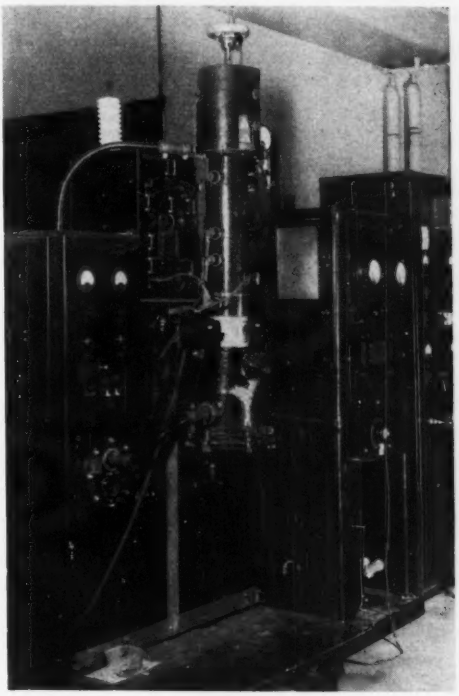

Fig. 1.
Industrial oscillograph

This material is based upon the unpublished thesis by LARKS, S. D.: "X-radiation from Television Picture Tubes and other Cathode Ray Tubes," Northwestern University, 1951.

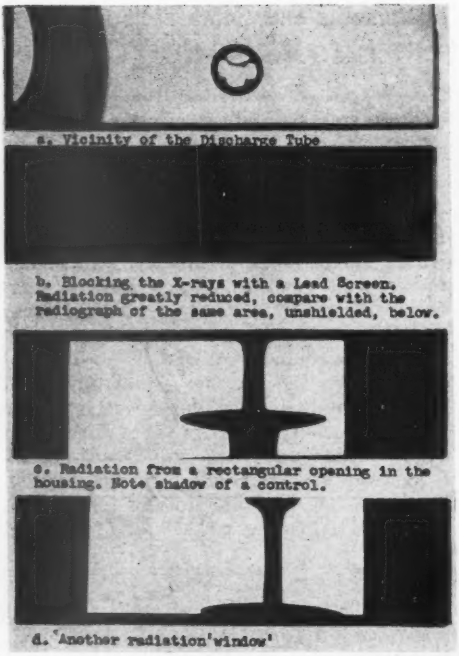
a. Vicinity of the Discharge Tube
b. Blocking the X-rays with a Lead Screen. Radiation greatly reduced, compare with the radiograph of the same area, unshielded, below.
c. Radiation from a rectangular opening in the housing. Note shadow of a control.
d. 'Another radiation window'

Fig. 2.
Radiographs from an industrial oscillograph

charge tube. In the path of the direct beam emerging from these points, radiation equal to or above the tolerance dose was noted at three feet from the instrument in question. (The currently-recommended tolerance dose is .3 roentgen per week, or about 6.25 milliroentgen per hour.)

As a further technique for the survey it was decided to use photographic, or, rather, x-ray, film. The use of the film technique enables much more precise localization of the radiation source if care is used and also permits quantitative determination of the roentgen dose. Radiographs using x-ray film were taken at the points of maximum intensity mentioned, the immediate vicinity of the discharge tube and the rectangular openings in the housing. With an exposure of three hours, the results were as indicated in Fig. 2 and can be interpreted as follows:

1. In the vicinity of the electron gun and discharge tube, the radiation is of the order of 1 roentgen. This of course is a level far above tolerance.

2. The radiation emerging from the side rectangular openings is of the order 1.5 to 2 roentgen. The radiographs here show good shadows of metallic controls in the path of the beam.

3. In Fig. 2b we see that a sheet of one-eighth inch or so lead, placed across one of the openings, has greatly reduced the emergent radiation. It should be noted, however, that even this reduction leaves some emergent radiation.

From the point of view of the inspector or field worker, assuming that an instrument of this type is in use in the field, the investigative or corrective measures which need to be taken are as follows:

1. A survey needs to be made similar to the above.

2. Metallic shielding needs to be installed

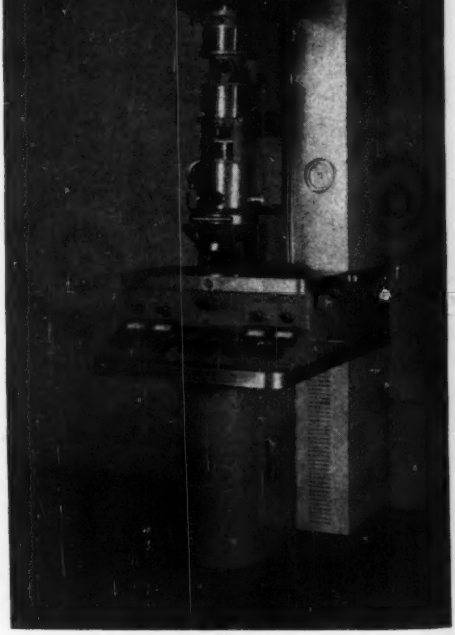

Fig. 3.
Electron microscope

around the cathode area, so that the bulk of the x-rays are absorbed. Lead is usually used.

3. Plate glass in the vicinity of the critical areas should be replaced with lead glass.

4. A health physics program should be instituted for operating personnel. This program should include the wearing of personnel monitoring devices such as film badges or pocket ionization chambers, and their proper evaluation by personnel or organizations set up for this purpose.

II. AN ELECTRON MICROSCOPE: An electron microscope of the type indicated in Fig. 3 may be considered to be a cathode-ray tube of a modified type. In this instrument an object of interest is interposed in the electron beam, and an elaborate system of electrostatic or electromagnetic lenses is used to magnify and define the shadow or image. Since the accelerating potentials involved are of the order of 50 kilovolts the possibility of emergent x-radiation exists.

The initial survey using a Geiger-Muller counter established the existence of x-radiation at the following specific areas:

1. Vicinity of the electron gun
2. Diffraction port
3. Intermediate viewing port
4. Final viewing chamber

From a quantitative point of view, the maximum intensity appeared to be emerging from the final viewing chamber when the image screen was tilted about 30°. Under this condition the reading of the G-M counter was of the order of 12 milliroentgen per hour, considerably above tolerance. At other points the radiation appeared to be of the order of magnitude of the tolerance dose, or about 6 mr/hr.

For further confirmation, radiographs using x-ray film were made, as in the first example given above. On the basis of an approximate 15-hour exposure, the evaluation of the resultant film density gave results as follows:

Final Viewing Chamber (screen not tilted)	.05 roentgen
Diffraction Port	.13 roentgen
Electron Gun Housing edge	.175 roentgen

The radiographs themselves are shown in Fig. 4, and it should be borne in mind

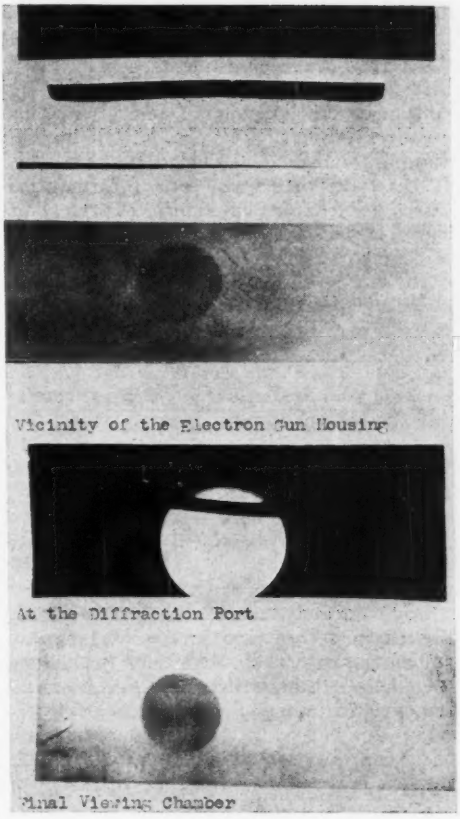

Fig. 4.

X-Ray output from an electron microscope. Various metallic objects have been used to determine the orientation of the radiation.

that since these are positive prints, the relatively bright areas show the absorption of x-rays. The first radiograph in this group for instance shows the wide beam of rays emerging from the edge of the electron gun housing, and the contrasting shadow of a lead strip. Radiation above the accepted safety level was definitely indicated in the second and third source areas, while above-tolerance radiation emerged from the first listed source when the screen was tilted, a position used for image photography. Corrective measures here are very similar to those previously discussed.

Biological Effects

IN CONNECTION with the consideration of electron-beam instruments as low intensity x-ray sources, the question of the significance, biologically, of such radiation, requires evaluation. A resume of current thinking on the subject is in order and is herewith presented. For informational purposes, a chart on known biological effects is included. It will be noted that biological effects are known to exist for quite low levels of irradiation. It may be observed that the tolerance dose at present is .3 r per week, or about 5 mr per day.

Dose per day	Radiation source	Biological Effect
.0001 r	Cosmic rays, sea level	
.003 r	Ra in water, Radon & thoron in air, etc.	Biologic action in *Drosophila*
.01 r	.1 ug Ra in skeleton, air containing radon, 10^{-10} curie per liter	Blood changes probable after considerable time.
.1 r	1 microgram Ra in skeleton	Inactivation of catalase, blood changes confirmed.

Body organs such as the blood-forming tissues and the reproductive organs are among the most radio-sensitive. It has long been known that irreversible mutations in the genetic materials are produced by x-rays. One subject of persistent search has been the question of a threshold, i.e., is there a lower limit such that radiation of a still lower intensity produces no effect? The most recent work in this field indicates that there is no threshold, a lower intensity of irradiation produces a lesser effect, but still an effect.[1] Another authority[2] states:

"Since radiation dosages appear to be cumulative as far as genetic changes are concerned, any dose of radiation, no matter how small, increases the probability of genetic changes. This means that even the so-called 'tolerance' dose of .3 rem per week, amounting to a maximum total of 300 rem in the course of 20 years' exposure, might not be negligible from the genetic point of view, although its direct physical effects would probably not be significant."

The Tolerance Dose and Blood Changes

ONE of the earliest observable changes which occurs after chronic irradiation at low intensities is the change in the blood picture. In one group of studies made[3] using laboratory animals, irradiation of .1 r per day (at that time the tolerance dose) produced a 20% drop in the white blood cell count, and a 15% drop in the lymphocyte count. The red blood cell count was slower in showing the change, but also begins to drop off at somewhat higher irradiation levels.

Other workers have noticed a change in the blood platelet[4] count upon prolonged low intensity irradiation, and have therefore recommended that the platelet count be included in radiation monitoring diagnostics: while at the University of Rochester further investigations are being conducted to confirm the usefulness of the appearance of double-nucleated cells as early indicators of radiation damage. It may be noted that even a return of the blood picture to almost normal after the cessation of irradiation does not necessarily mean a return to normal health. The cited blood changes occur at the tolerance level or below.

Effects of Low Intensity Irradiation

INCREASING evidence and opinion exists to the effect that prolonged irradiation at low intensity levels leads to premature aging or acceleration of the aging process. A number of years ago, a foremost worker in the field of hematology presented evidence for the thought that "cells grow older more rapidly when exposed to the effects of radiation"[5] .... That present-day thinking is in accord with this earlier view is indicated by Muller and Boche. Muller[6] discusses Boche's remarks as follows: "Boche finds that even at levels as low as what has hitherto been accepted as the so-called tolerance dose, namely, .1 r per day, when these dosages are applied persistently to mature animals for the remainder of their lives, there is a significant lowering of their expectation of life. This is expressible as a shortening of the average duration of life,—perhaps as though the animals were aging more rapidly ....

"The same formula applied to man would lead to the conclusion that the so-called tolerance dose of .1 r per working day, persistently applied, would result in an aver-

age shortening of life of about three years, and that the proposed new 'permissible dose' of .3 r per week would shorten it by about a year and a half."

Leukemias and Other Cancers

RECENT statistical studies of mortality figures among physicians, and especially and specifically among radiologists, have indicated that the incidence of leukemias in this group is more than eight times as great as among physicians generally, and considerably higher than among the population as a whole. This significant difference has been attributed to the effects of low levels of radiation absorbed over a long period of time.

Among the studies of the subject made for the Manhattan District, one such study using laboratory animals showed results as follows:[7]

Leukemias	%
Controls	0
.1 r per day	1
.5 r per day	2
1.0 r per day	3
10.0 r per day	12

From this it is seen that even at levels as low as .1 r/day there is an increase in the number of leukemic animals. Similar investigations made with other laboratory animals showed the development of ovarian tumors as a result of .1 r/day irradiation. Lorenz[8] points out that carcinogenic action and sterility effects dominate the picture of radiation injury and hence argues for a reduction of the tolerance dose to .02 r per day, at least for women.

Skin Damage

THE evidence of skin damage as shown by the hands of radiologists is quite impressive. Nickson[9] points out that the incidence of abnormality among radiologists was 48% as compared to 1.8% of an unexposed group, and that the incidence of ridge abnormality increased with years of exposure to 100%. It is further pointed out that the specific types of skin change noted may be induced by repeated low dose exposure to radiation, and, like other biological effects of radiation, cannot be distinguished from similar findings in very old persons.

On the basis of the brief dissertation presented here on the biological effects, it can be seen that these are by no means negligible. The full import can best be realized if one bears in mind also the following:

1. Radiation effects are cumulative, i.e., prolonged low intensity irradiation over a long period of time has a cumulatively damaging effect.
2. Short periods of intense irradiation will also cumulatively add their effects to that of the low-intensity effect.
3. Different types of radiation, Gamma, Beta, X, also have a cumulatively damaging effect, although the combined effects do not add linearly.

Hence, the possible significance of the effects of prolonged irradiation from cathode-ray tube sources cannot be considered alone, but must be taken into account as the effect of an additional, 'new' source of radiation in combination with the existing 'normal' level.

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BACK ISSUES AVAILABLE

Single copies of nearly all issues of the AIHA Quarterly, since its appearance in June, 1946, as a separate journal, may be obtained from the Executive Secretary.

Objectives and Recommendations for Education in Industrial Health

Report of the Education Committee—American Industrial Hygiene Association
April, 1950
Accepted by Board of Directors April, 1951

Part I. Objectives of Industrial Hygiene Education

INDUSTRIAL hygiene is a field of applied sciences, depending upon the joint contributions and teamwork of individuals from several professions: chemistry, physics, physiology, medicine, engineering. The needs for and nature of advanced education and training, therefore, are not immediately evident, as they are in the case of any one of the contributing professions. There is a considerable group of special techniques and items of particular knowledge which constitute the major tools in industrial hygiene practice but, in themselves, they probably do not warrant the development of extensive programs of graduate education. Rather, the basic concepts and principles are the matters of chief concern in consideration of the needs for such advanced education and training. The most important characteristic of the industrial hygiene specialist, which distinguishes him from his own professional colleagues, is the extension of his knowledge and skills beyond the usual limits of his own profession into the other basic fields which contribute to industrial hygiene practice. A second characteristic of major significance is the development of teamwork among the several professions, to a degree beyond the usual experience in these professions, which requires considerable knowledge in common and a keen understanding by each member of the group of the contributions and methods of study employed by the other members. Finally, there is a common appreciation of the statistical nature of problems having to do with relationships between man and his environment which helps to resolve the apparent conflict between the principles and procedures of the physical sciences, which are based upon rather precise mathematical relationships, and those of the medical sciences, which emphasize the complexity and variability of man and his reaction.

The primary objectives of graduate training in industrial hygiene, then, are to develop these distinguishing characteristics and principles, as well as to provide extended education in medicine, engineering, etc., and training in the special techniques of each of these professions which are employed in industrial hygiene practice.

Part II. General Recommendations

A. UNDERGRADUATE AND GRADUATE EDUCATION:

The committee considers that a sound education in the basic sciences at the undergraduate level is the most important prerequisite for work in industrial hygiene. (In connection with this it would seem desirable that college students be informed of the field of industrial hygiene and the basic training which is desirable at the college level.)

The committee believes that industrial hygiene is a profession for which specialized training is desirable at the graduate level. The fundamental reasons for this are expressed in Part I; the type of graduate education is outlined in Part III.

B. QUALITY OF EDUCATION:

The committee recommends that graduate education in industrial health should be at an academic level equivalent to first class training in medicine and engineering. Such training should, if desired, lead to advanced degrees such as the Doctor of Science or Doctor of Philosophy. The committee does not favor the use of degrees which are specific to the field of industrial hygiene such as "Doctor of Industrial Hygiene."

C. TYPE OF UNIVERSITY WHICH SHOULD OFFER GRADUATE EDUCATION:

The committee believes that graduate education should be given preferably in universities where graduate work in chemistry, physics, engineering, preclinical medicine and public health or preventive medicine is offered. It is especially recommended that graduate education for all types of industrial hygiene personnel be

given at the same university, since as discussed in part I, this field requires the closest cooperation of chemists, physicists, engineers and medical personnel.

D. SHORT COURSES, REFRESHER COURSES AND ORIENTATION COURSES FOR OTHER PROFESSIONS:

The committee recognizes that short courses, refresher courses and orientation courses are necessary and desirable, but they feel that this report should not attempt to cover this type of education in detail.

It is recommended that all graduate schools giving specialized training in business management, industrial engineering, chemical engineering, etc., include some orientation course in industrial health so that all branches of industry will be aware of the health problems of industrial workers. It is also recommended that all medical schools and public health schools include at least some orientation courses in industrial health since all public health departments will be required to deal with industrial health problems and all doctors will deal with patients who spend the greater part of their life in some occupation.

E. FIELD TRAINING AND IN-SERVICE TRAINING:

All members of the committee are agreed that practical field training is essential. Some members of the committee believe that, given a sound college education in the basic sciences, the specialized training in industrial hygiene can be obtained best by practical work (in-service) supplemented with some formal training. Other members of the committee believe that formal training is essential as a basis for practical experience if industrial hygiene is to be a profession and not a technique.

This report is directed primarily toward the more formal type of education which is believed desirable, although the need for practical training is considered equally important.

Part III. Recommendations Regarding Specialized Education for Work in Industrial Hygiene

IT IS apparent that the accomplishment of the normal functions of the industrial hygiene services may require specialized training in a number of fields of human knowledge including: mathematics, chemistry, administration, engineering, physics, and medicine. It is apparent that no single individual can be expected to supply the knowledge and techniques necessary adequately to carry out these diversified functions. This report, therefore, will present the committee's recommendations concerning the educational requirements of the various types of personnel required for an adequate Industrial Hygiene Service.

A. UNDERGRADUATE EDUCATION:

The undergraduate education for all types of personnel planning to enter the field of industrial health should supply sound training in the basic sciences of chemistry, including, if possible, analytical and physical chemistry, mathematics, including, when necessary, analytical geometry and calculus, physics and biology. For certain classes of industrial hygiene personnel engineering is a fundamental requirement. The proportions of time allotted to each of these subjects will depend on the phase of industrial hygiene in which the individual desires to specialize.

The importance of sound basic education in the physical sciences at the undergraduate level cannot be over emphasized.

B. GRADUATE EDUCATION IN INDUSTRIAL HYGIENE FOR ENGINEERS, CHEMISTS, BIOPHYSICISTS AND MEDICAL SCIENTISTS:

Graduate education should extend for at least one year and should consist of both formal education and practical training. The type of training will vary according to whether the person plans to go into general work in industrial hygiene, chemical analytical work, physical biology, ventilating engineering, toxicology, or the other medical sciences related to industrial health. However, education in certain subjects are necessary for all groups. These include biostatistics and epidemology; industrial toxicology and occupational diseases; biophysics; industrial physiology, including the physiological effects of the environment and work and the physiological designs of work; industrial sickness and accidents; industrial hygiene methods and procedures (laboratory and field); administrative and legal aspects of industrial hygiene; and other topics.

In addition the chemists will require ad-

vanced training in chemistry, chemical engineering; the physical biologists will require advanced physics, radiation physics, and other specialized subjects; the ventilating engineers will require specialized engineering training; the industrial hygiene engineers will require some training in business organization, industrial processes, more training in factory hygiene sanitation, industrial wastes, safety engineering, etc.; and the medical science personnel will require training in the basic medical sciences (anatomy, physiology, pathology, pharmacology, and biochemistry). Some types of personnel will require training in the medical, social and economic factors in the selection and placement of workers.

If only one year is allowed for graduate education the type and extent of the courses will have to be fitted to the needs and time of that particular group. The above recommendations are presented only to indicate the pattern of education which is considered desirable.

Laboratory, clinical and field training should be an integral part of the postgraduate work. Persons going into research in industrial hygiene should undertake also some original research. This would require additional years of graduate work.

Practical experience under actual working conditions is considered a necessary part of the training program. Some members of the committee feel that this should precede the postgraduate educational program. Other members believe that it should follow the more didactic training.

C. EDUCATION FOR NURSES IN INDUSTRIAL HYGIENE:

This committee did not consider the educational requirements in the field of industrial hygiene for graduate nurses since this group has its own organization for this purpose.

D. GRADUATE EDUCATION FOR PHYSICIANS:

It is not the function of this committee to recommend the type of education for physicians who are going into industrial health positions in public agencies or in private industry since this group has its own organizations for this purpose. However, this committee wishes to endorse the general recommendations of the medical committees, namely, that orientation training in industrial hygiene should be a part of the medical school curriculum and that specialized post-graduate training is necessary for physicians who plan to practice industrial medicine or to work in a private or governmental industrial health agency.

THE CHIEF point this committee would like to emphasize is the necessity for integrating the education of all groups—engineers, chemists, physicists, medical scientists and physicians—at the graduate level. This is not only desirable because the type of training will be the same in many instances but also because joint training, as far as possible, will lead to a broader understanding of the problems of industrial health and a greater ability of all groups to work together. As pointed out in Part I, industrial hygiene depends on the joint contributions and teamwork of all these professions.

—COMMITTEE ON EDUCATION:
DR. W. F. ASHE,
MR. H. G. DYKTOR,
MR. T. F. HATCH,
DR. H. C. HODGE,
DR. D. D. IRISH,
ANNA M. BAETJER, Chairman.

The President's Page

The Tenth International Congress of Industrial Medicine

THE TENTH International Congress of Industrial Medicine was held in Lisbon, Portugal, from September 9 to 15, under the auspices of the Permanent International Commission of Industrial Medicine. The Congress was arranged by the Local Organizing Committee, composed of outstanding professors and doctors in Portugal, and was held under the patronage of Their Excellencies, the President and Prime Minister of Portugal. Twenty-seven nations were represented at the Congress with a total of 843 active members, of whom approximately 500 were from countries other than Portugal. The largest delegations came from Great Britain, France, Finland, Brazil, and Spain. The World Health Organization, the International Labor Office, and the International Social Security Association also were represented. The members of the American Industrial Hygiene Association who attended the Congress were: Drs. A. M. Baetjer, H. Brieger, J. S. Felton, H. S. Kuhn, C. P. McCord, C. M. Peterson, H. E. Tebrock, and C. R. Walmer. The other participants from the United States were: Mrs. T. Durham and Miss S. P. Wagner (the American Association of Industrial Nurses), Brig. General O. B. Schreuder (Air Force), Captains R. W. Babione and J. P. Wood (Navy), Miss R. Stilwell (American Embassy), and Drs. R. T. Legge, E. Mayer, and F. Rieders.

The Congress was opened, at a formal meeting, by the Minister of the Corporations and Social Insurance of Portugal. The other speakers were the President of the Congress, the Chairman and Secretary of the Permanent International Commission, and a representative of the World Health Organization. During the following week, nine half-day technical sessions were held. On each day, one or two major reports were given by invited speakers. Following these, the members of the Congress presented 10-minute papers in several different sections which ran concurrently. French was the official language, but papers could be presented in other languages as designated by the Organizing Committee. All general meetings and one section of each session were translated into English and French through an IBM wireless translator system. Three clinical sessions were held in various hospitals in Lisbon. Approximately 200 papers were presented at the various sessions of the Congress. Slightly more than one-quarter of these dealt with industrial toxicology and occupational diseases. In this group of papers, the pneumoconioses were discussed more frequently than any other industrial diseases, most of the papers on the metals were devoted to mercury and lead; and only about a dozen papers dealt with organic compounds. About a quarter of the papers were devoted to descriptions of the medical care and social welfare programs for the working people of Portugal and other countries. Discussions of industrial accidents and traumatic injuries and their treatment occupied an important, although somewhat smaller, part of the program. The organization of medical and nursing services in industry was discussed by a number of industrial physicians and nurses; the latter were chiefly from the Scandinavian countries, Great Britain, and the United States. Industrial psychology, the physiology of work, rehabilitation, compensation, and nutrition were also considered in a few papers. The remainder of the program covered other health problems of the working people in various parts of the world and in specific industries. For the most part, the papers were general discussions of the problems under consideration rather than reports of scientific research or of technical advances. Practically no papers dealt with the very important engineering and chemical aspects of industrial health work.

The Congress was formally closed at a general meeting which was attended by His Excellency, the President of Portugal. The speakers at this meeting reviewed the various contributions made by the members of the Congress from all parts of the world,

emphasized the many problems in industrial health which remain to be solved, and paid tribute to the Government of Portugal and to the members of the Organizing Committee who were responsible for the success of the Congress.

In addition to the formal sessions, the Local Organizing Committee, the Ministers of Foreign Affairs and Corporations, and the President of the Lisbon Town Hall entertained the members of the Congress and their families at a number of social events, which made the meeting of the Congress a delightful and memorable occasion. The Committee arranged bus and boat trips so that the members of the Congress had the opportunity of seeing not only the beautiful country of Portugal and the many places of historic interest, but also some of the recent social welfare projects of the Portugese Government. These social events afforded an excellent opportunity for the members of the various countries to meet and discuss their work informally.

The most significant aspect of the Congress, however, was not the formal sessions or the informal discussions, but the fact that representatives from nations all over the world met together with the common purpose of discussing the health problems of working people and thus demonstrated the importance and world-wide interest in industrial health.

The next International Congress on Industrial Medicine is to be held in Naples, Italy, in 1954. It is hoped that many members of the American Industrial Hygiene Association will be able to attend and participate in the next Congress.

—ANNA M. BAETJER, SC.D.

THE BODY politic, like the human body, begins to die from its birth, and bears in itself the causes of its destruction.

—Rousseau

STATEMENT of the ownership, management, and circulation required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233), of American Industrial Hygiene Association Quarterly published quarterly at Sheboygan, Wis. for October 1, 1951. 1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Industrial Medicine Publishing Company, 605 North Michigan, Chicago, Ill.; Editor, Herbert J. Weber, American Brake Shoe Company, 2501 Blue Island Avenue, Chicago, Ill.; Managing Editor, none; Business Manager, none. The owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership, or other unincorporated firm, its name and address, as well as that of each individual member, must be given.) The American Industrial Hygiene Association (a non-incorporated association); Henry F. Smyth, Jr., Executive Secretary, Mellon Institute, Pittsburgh 13, Pa. 3. The known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None. 4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner. 5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.) A. D. Cloud, Publisher. Sworn to and subscribed before me this 3rd day of October, 1951. (Seal) Lucille H. Gross. (My commission expires February 14, 1955.)

American Industrial Hygiene Association

— News of the Local Sections —

Northern California Section

THE REGULAR meeting of the Northern California Section of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION was held Tuesday, September 18.

The program for the evening consisted of a discussion on the part of the membership regarding the relationship between health and labor departments in the matter of occupational disease and accident prevention.

DR. HERBERT K. ABRAMS started the discussion by reading a proposed draft of a committee of which he was chairman and which had been appointed by the APHA Industrial Hygiene Section to develop a statement of policy on industrial hygiene in government. The other members of the committee with whom DR. ABRAMS has been corresponding are: R. R. SAYERS and F. A. PATTY. This statement was discussed at considerable length by various members of the Section.

The second portion of the program was a review of a new amendment to the Labor Code passed by the 1951 session of the California Legislature having to do with prorating of silicosis claims in underground metal mines where the employee had worked in and been exposed to silica in more than one employment. In brief the statutes provided that although the last employer would be held liable, the principle of apportionment between other employers was affirmed and the means for establishing the pro rata portion of liability among previous employers was specified. If previous employers were no longer existent or out of the jurisdiction of the State, payment for that portion of the compensation benefits would be made from the Subsequent Injury Fund.

Another point of interest in the bill was the statement that the Industrial Accident Commission could accept as evidence dust counts that were properly made to show that the employer maintained a safe place of employment insofar as exposing his employees to hazardous concentrations of toxic dusts.

Metropolitan New York Section

THE SECTION met September 26, at the Lower East Side Health Center.

The speakers, DR. R. E. ECKHARDT and N. V. HENDRICKS, discussed "Occupational Cancer—Epidermiology and Control." They are associated with the Medical Research Division of the Esso Laboratories.

DR. ECKHARDT presented the medical and biological aspects of an occupational cancer problem and MR. HENDRICKS covered the epidermiology and industrial hygiene phases.

Warren Cook

Miriam Sachs

On November 7, WARREN COOK of Zurich Insurance Company and DR. MARIAM SACHS, Acting Chief of the Division of Adults and Industrial Health spoke on maximum allowable concentrations. MR. COOK discussed the limitations and DR. SACHS the value of M.S.C.'s.

Ohio Valley Section

ON OCTOBER 17, DR. ROBERT A. KEHOE, Professor of Industrial Medicine and Director of the Department of Preventive Medicine and Industrial Health, University of Cincinnati, spoke to the Ohio Valley Section of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION on "Milestones of Industrial Hygiene." The meeting was held at the Kettering Laboratory.

Michigan Section

THE FIRST regular meeting was held in Detroit October 12. The meeting was in the nature of a banquet in honor of DR. CAREY P. MCCORD, who recently retired from the consulting field to join the University of Michigan Medical School as a lecturer on Industrial Health. Approximately 120 persons attended, including representatives from the Michigan Industrial Physicians Club and the Michigan Industrial Nurses Association, who were co-sponsors of this joint meeting. President RALPH SMITH presented DR. MCCORD with a certificate as first honorary life member and DR. SELBY of the University of Michigan School of Public Health introduced the guest of the evening.

DR. MCCORD addressed the group on various topics connected with his long and varied

career as an industrial physician and industrial hygienist. Of particular interest was his account of the World Industrial Health meeting which he recently attended in Lisbon, Portugal.

News Items

DR. D. JOHN LAUER, former Assistant Professor of Industrial Medicine at the University of Cincinnati and plant physician for several firms in the Ohio city, has been appointed Medical Director of the Jones & Laughlin Steel Corporation. He will direct and supervise the employee health program of the Corporation and its medical facilities in its plants and factories throughout the United States.

DR. LAUER is a graduate of the Medical School of the University of Minnesota and earned one of the nation's first doctorate degrees in Industrial Medicine, from the University of Pittsburgh. Following general practice in his native city, St. Paul, Minnesota, DR. LAUER served a five year period in the U.S. Navy during World War II as an industrial medical officer, with the rank of Commander. He comes to Jones & Laughlin Steel Corporation direct from the Kettering Laboratory at the University of Cincinnati. In addition to his duties as Assistant Professor of Industrial Medicine there, DR. LAUER was active in organizing in-plant health programs in the smaller industries. He also served as plant physician for the Hilton-Davis Chemical Company and the Davison Chemical Company, and served as consultant for Proctor and Gamble.

DR. LAUER is a specialist in Industrial Medicine, a field which includes such sub-divisions as occupational diseases, preventive health in our industrial populations, in-plant health programs, etc.

DR. LAUER is a fellow and member of the American Medical Association, the Industrial Medical Association, the American Public Health Association, the American Academy of Occupational Medicine, and he is a member of the American Industrial Health Association, the American Association for the Advancement of Science, and the American Industrial Hygiene Association. He is President of the Ohio Valley Section of the American Industrial Hygiene Association.

Necrology

DR. ROY SCHNEITER, Principal Bacteriologist, U.S. Public Health Service, Division of Occupational Health, Field Headquarters, Cincinnati, Ohio, died of a heart attack, October 5.

Dr. Schneiter received his B.S. and M.S. at Iowa State in 1927 and 1929 respectively, and his PhD. from the University of Maryland in 1943. He was employed as a bacteriologist by the U.S. Food and Drug Administration from 1928 to 1940, and since that time by the U.S. Public Health Service.

DR. SCHNEITER was author or co-author of about 30 publications. His current investigations concerned industrial anthrax and two papers on this subject were recently submitted for publication. He spent several years investigating the cause of illness among workers using low-grade stained cotton.

His many friends mourn his sudden, tragic death. He is survived by his wife and son.

THE BRITISH Bureau of Hygiene and Tropical Diseases announces the beginning publication of a *Bulletin of Hygiene Reprints*, containing sections of its main *Bulletin of Hygiene* which deal with occupational hygiene, atmospheric pollution, occupational psychology, physiology as applied to hygiene, and the hygiene of buildings. The abstracts in these sections are printed separately so that they may be made more readily available to industrial engineers, works managers, welfare officers and others in industry who are directly concerned with the well-being and efficiency of workers, but who, as non-medical men, are less concerned with the other sections of the *Bulletin of Hygiene* which relate to preventive medicine generally, including communicable diseases, and bacteriology and immunity and related subjects of public health interest. The subscription price for the monthly *Bulletin of Hygiene Reprints*, sent post free to the United States, is $3.00 per year. Subscriptions should be sent to R. L. Sheppard, Secretary, Bureau of Hygiene and Tropical Diseases, Keppel Street, Gower Street, London, W.C.1.